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(54) **METHODS AND APPARATUS FOR FACILITATING ROBUST FORWARD HANDOVER IN LONG TERM EVOLUTION (LTE) COMMUNICATION SYSTEMS**

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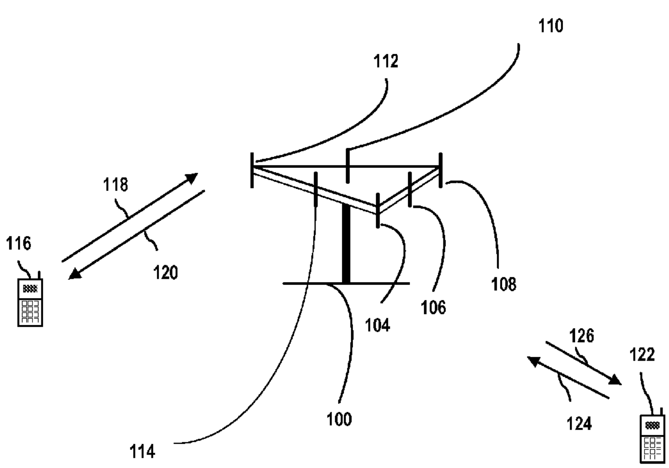
(57) **ABSTRACT**

Method and apparatus for facilitating inter-cell connections, such as during a forward handover or radio link failure (RLF), are disclosed. A user terminal such as a UE may store identity information associated with a source cell, and use this information in accessing target or other cells subsequent to radio link failure so as to facilitate access to context information of the user terminal. A base station may be configured to improve handover performance by associating context information with a newly assigned terminal identity. Handover performance may be enhanced by facilitating connection processing in the event of inability to retrieve user terminal context from a source cell.

20 Claims, 18 Drawing Sheets



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WO	0041426	A1	7/2000
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WO	03017582		2/2003
WO	03092316	A1	11/2003
WO	03098816	A2	11/2003
WO	03105516	A1	12/2003
WO	2004068739	A1	8/2004
WO	2004070989		8/2004
WO	2004075468	A2	9/2004
WO	2004079949	A1	9/2004
WO	2004105272	A1	12/2004
WO	2004107638	A2	12/2004
WO	WO-2004114695	A1	12/2004
WO	2005029790		3/2005
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WO	WO-2008131401	A1	10/2008

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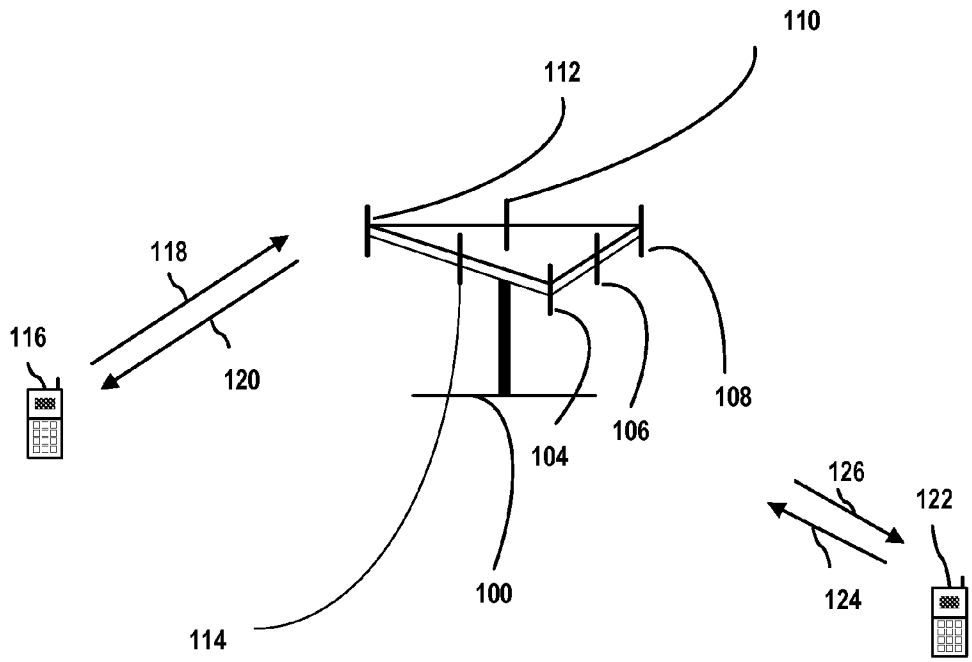
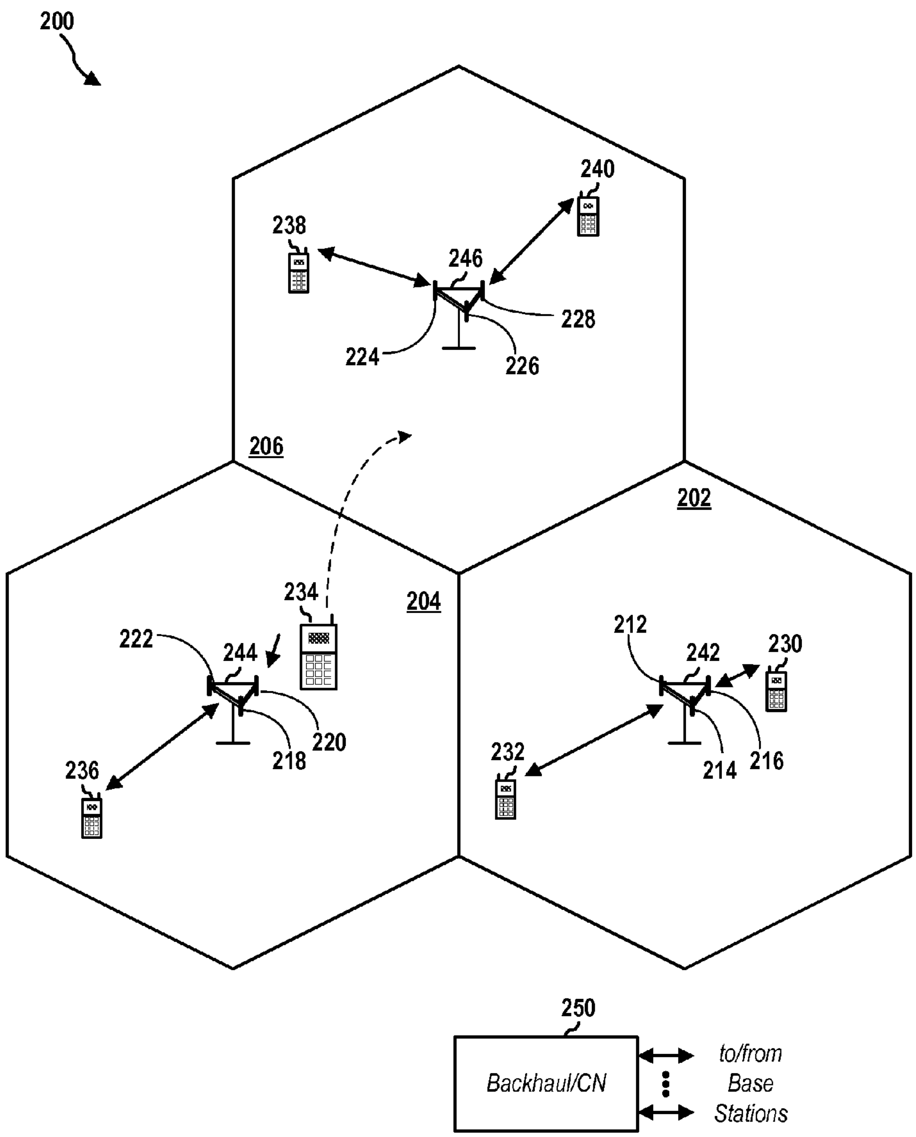


FIG. 1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240
238
246
228
224
226
206
202
234
204
222
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212
242
230
220
218
236
232
214
216
250
Backhaul/CN
to/from
Base
Stations

FIG. 2

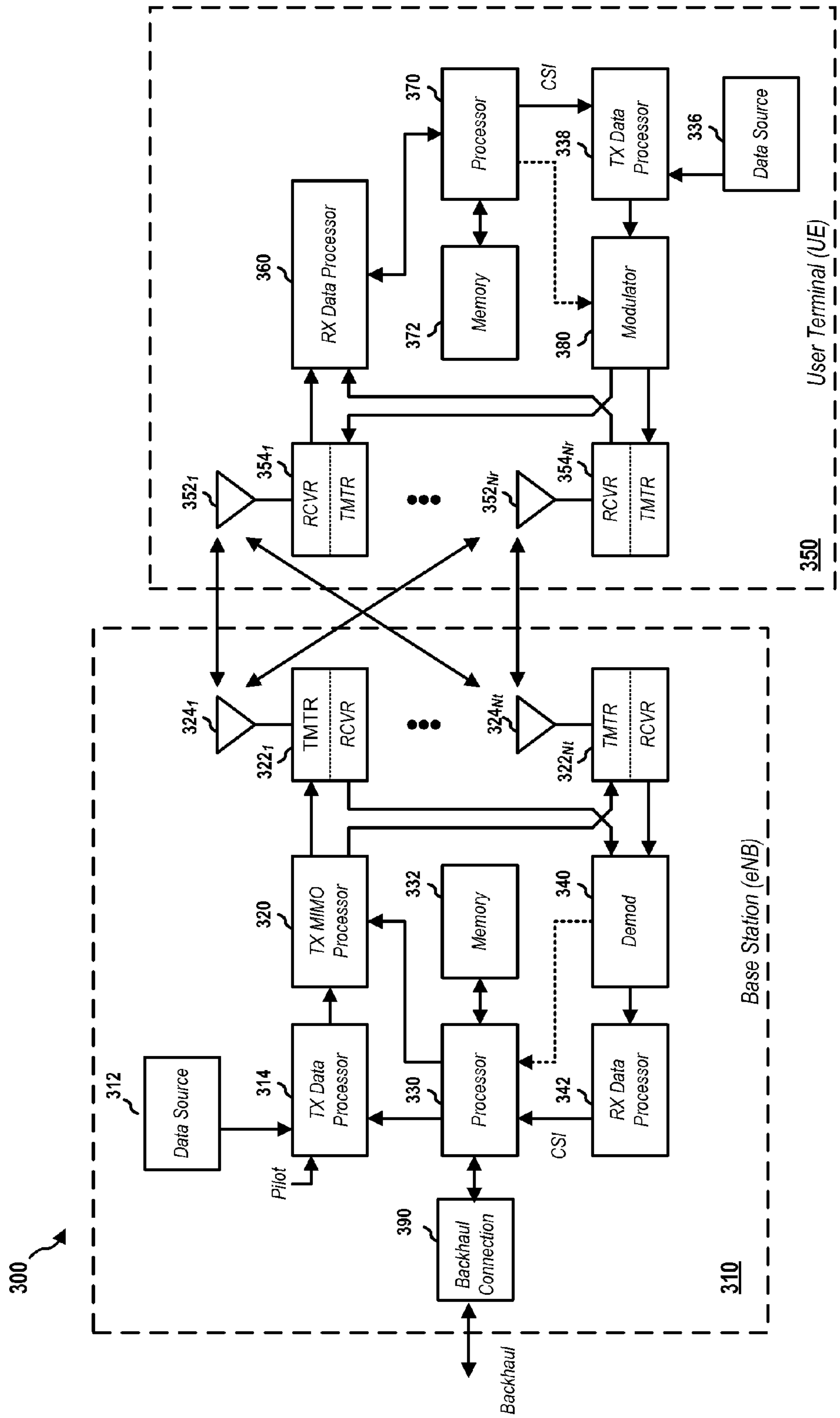

300
310
Base Station (eNB)
Data Source
312
TX Data Processor
314
Pilot
TX MIMO Processor
320
Memory
332
Processor
330
Demod
340
RX Data Processor
342
CSI
Backhaul Connection
390
Backhaul
TMTR
RCVR
322₁
324₁
322Nt
324Nt
350
User Terminal (UE)
RX Data Processor
360
Processor
370
Memory
372
CSI
TX Data Processor
338
Data Source
336
Modulator
380
RCVR
TMTR
352₁
354₁
352Nr
354Nr

FIG. 3

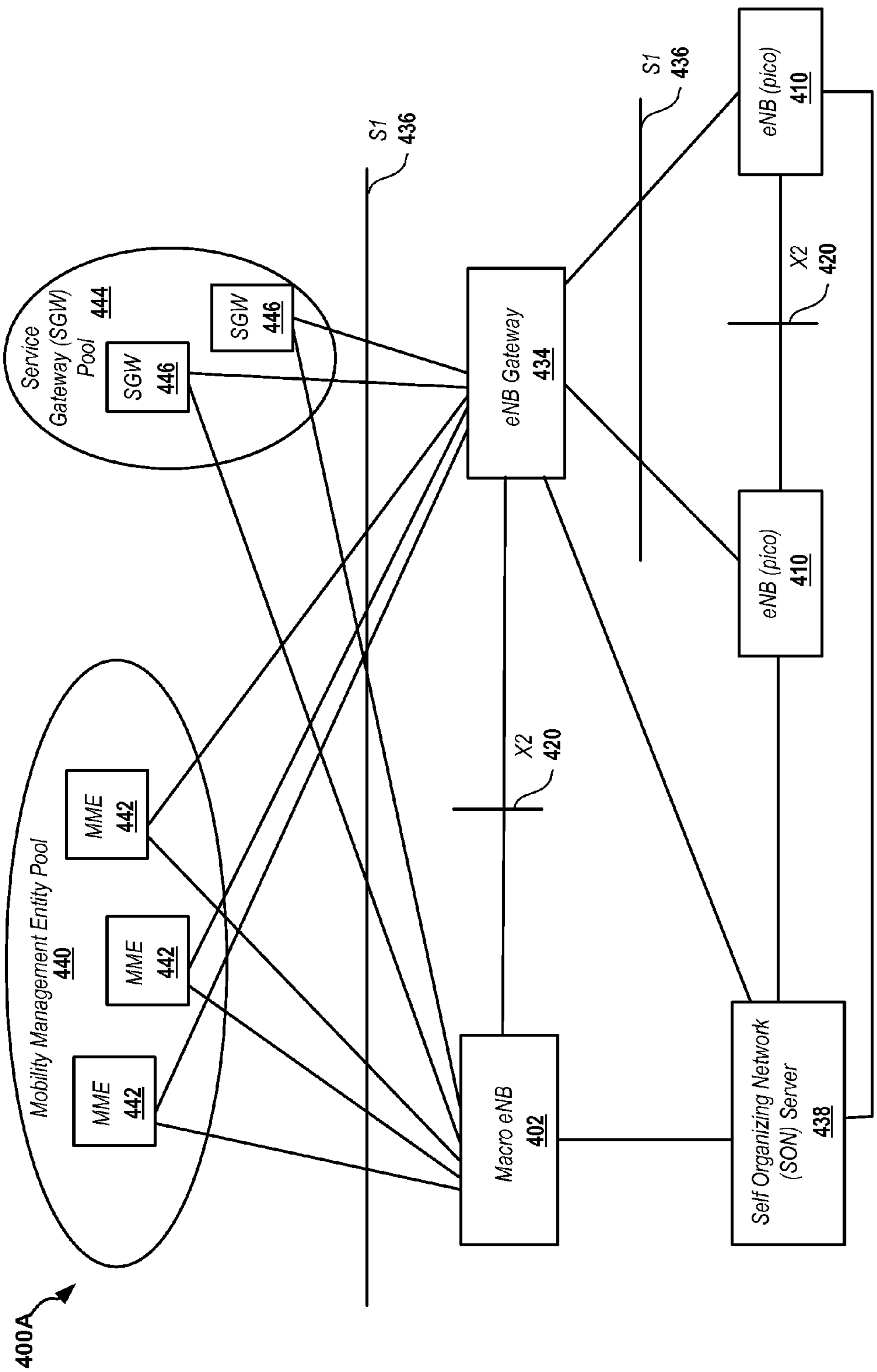

400A
Mobility Management Entity Pool
440
MME
442
MME
442
MME
442
Service Gateway (SGW) Pool
444
SGW
446
SGW
446
S1
436
S1
436
eNB Gateway
434
X2
420
X2
420
eNB (pico)
410
eNB (pico)
410
Macro eNB
402
Self Organizing Network (SON) Server
438

FIG. 4A

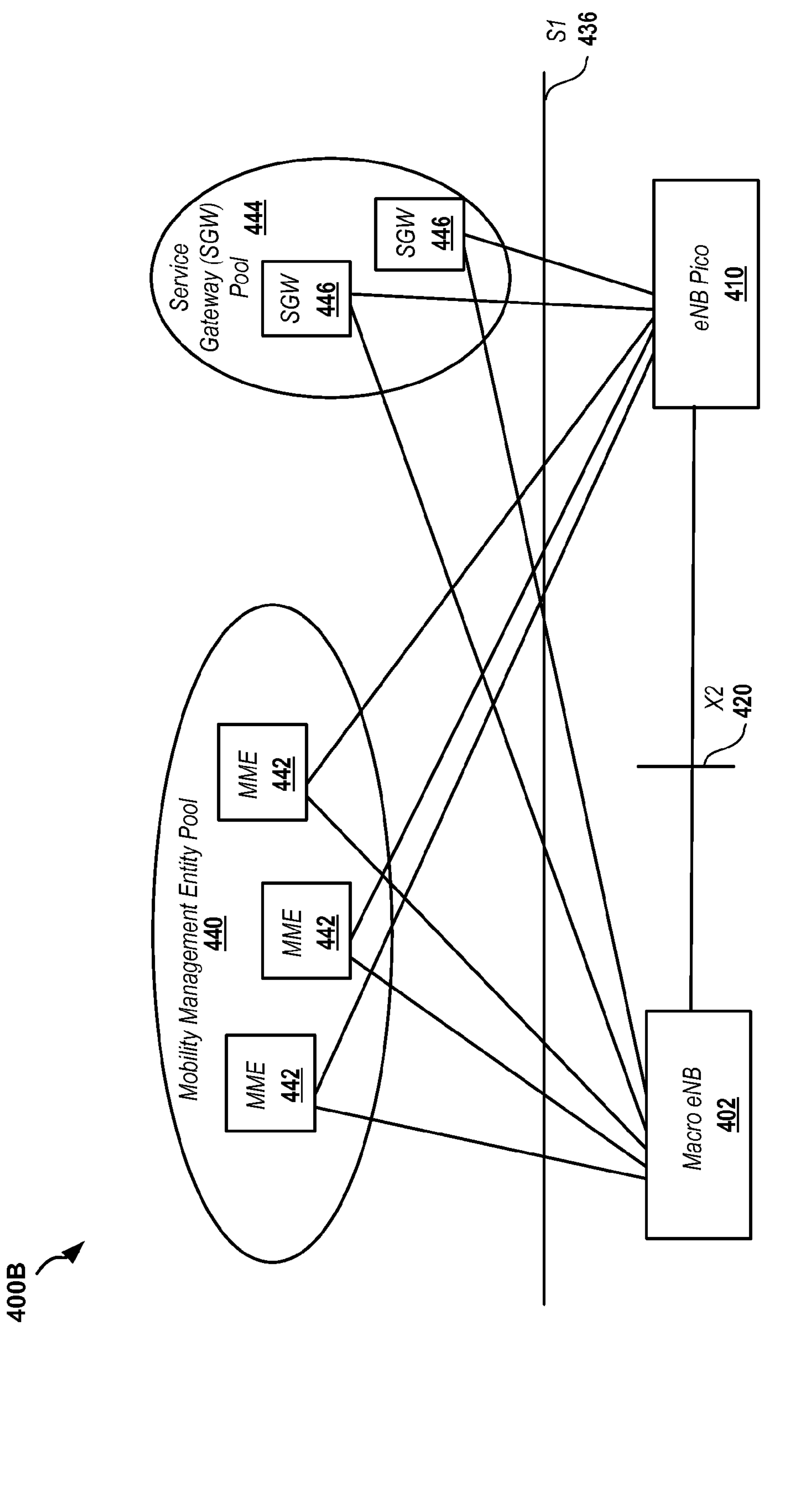

400B
S1
436
Service Gateway (SGW) Pool
444
SGW
446
SGW
446
eNB Pico
410
X2
420
Mobility Management Entity Pool
440
MME
442
MME
442
MME
442
Macro eNB
402

FIG. 4B

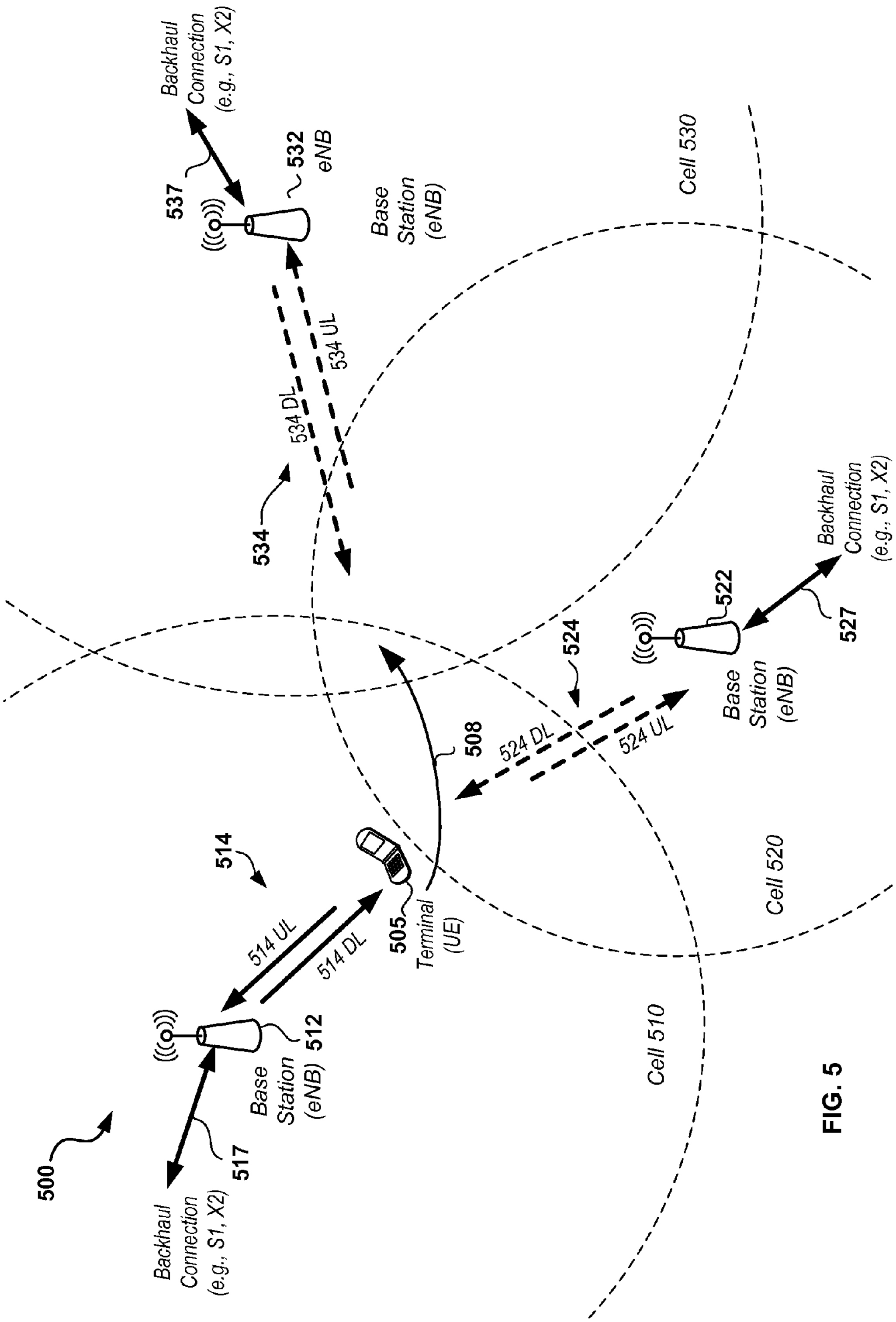

500
Backhaul Connection (e.g., S1, X2)
517
Base Station (eNB)
512
514 UL
514 DL
514
505
Terminal (UE)
508
Cell 510
Cell 520
524 DL
524 UL
524
Base Station (eNB)
522
527
Backhaul Connection (e.g., S1, X2)
534
534 DL
534 UL
537
532
eNB
Base Station (eNB)
Backhaul Connection (e.g., S1, X2)
Cell 530

FIG. 5

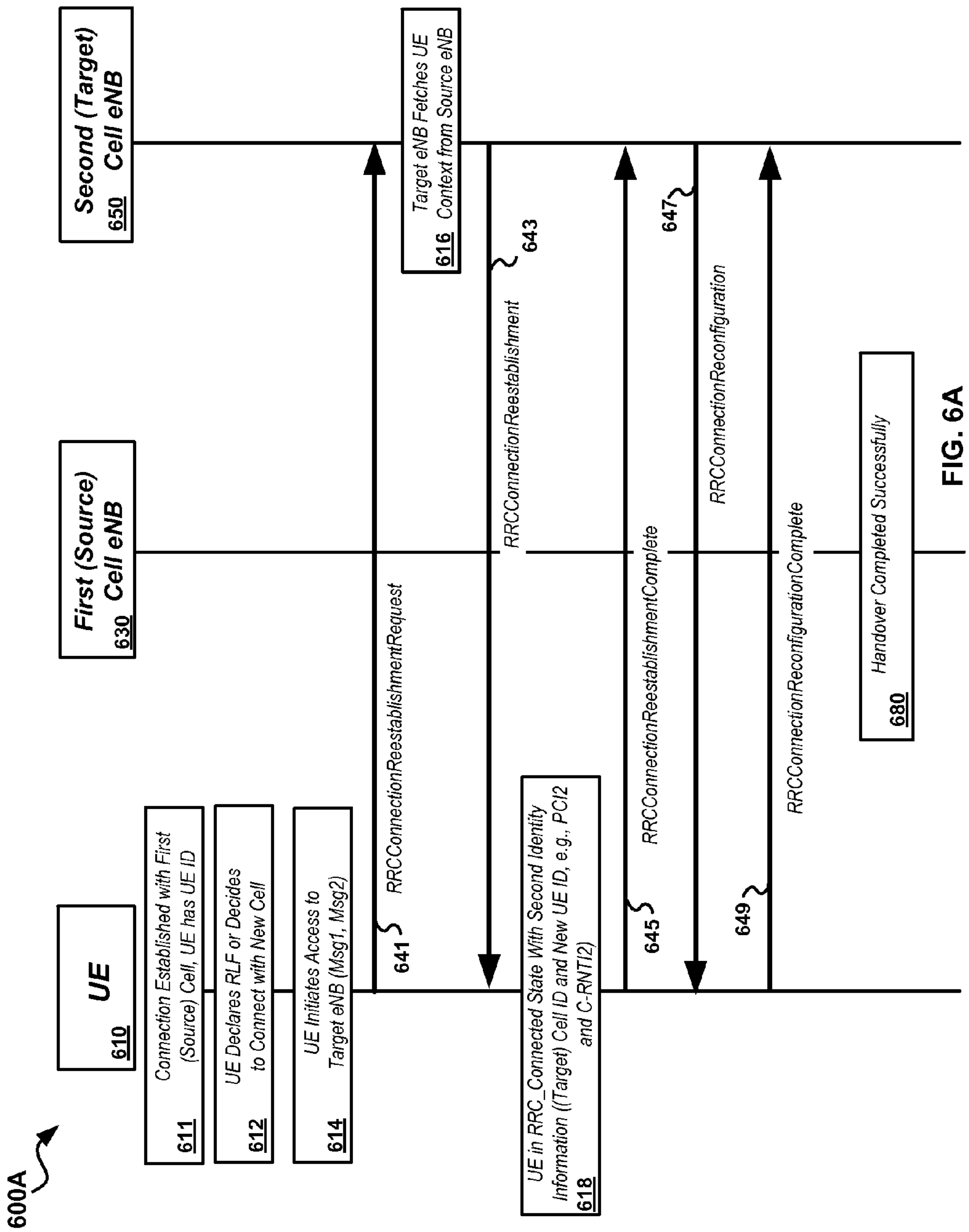

600A
UE 610
First (Source) Cell eNB 630
Second (Target) Cell eNB 650
611 Connection Established with First (Source) Cell, UE has UE ID
612 UE Declares RLF or Decides to Connect with New Cell
614 UE Initiates Access to Target eNB (Msg1, Msg2)
641
RRCConnectionReestablishmentRequest
616 Target eNB Fetches UE Context from Source eNB
643
RRCConnectionReestablishment
618 UE in RRC_Connected State With Second Identity Information ((Target) Cell ID and New UE ID, e.g., PCI2 and C-RNTI2)
645
RRCConnectionReestablishmentComplete
647
RRCConnectionReconfiguration
649
RRCConnectionReconfigurationComplete
680 Handover Completed Successfully

FIG. 6A

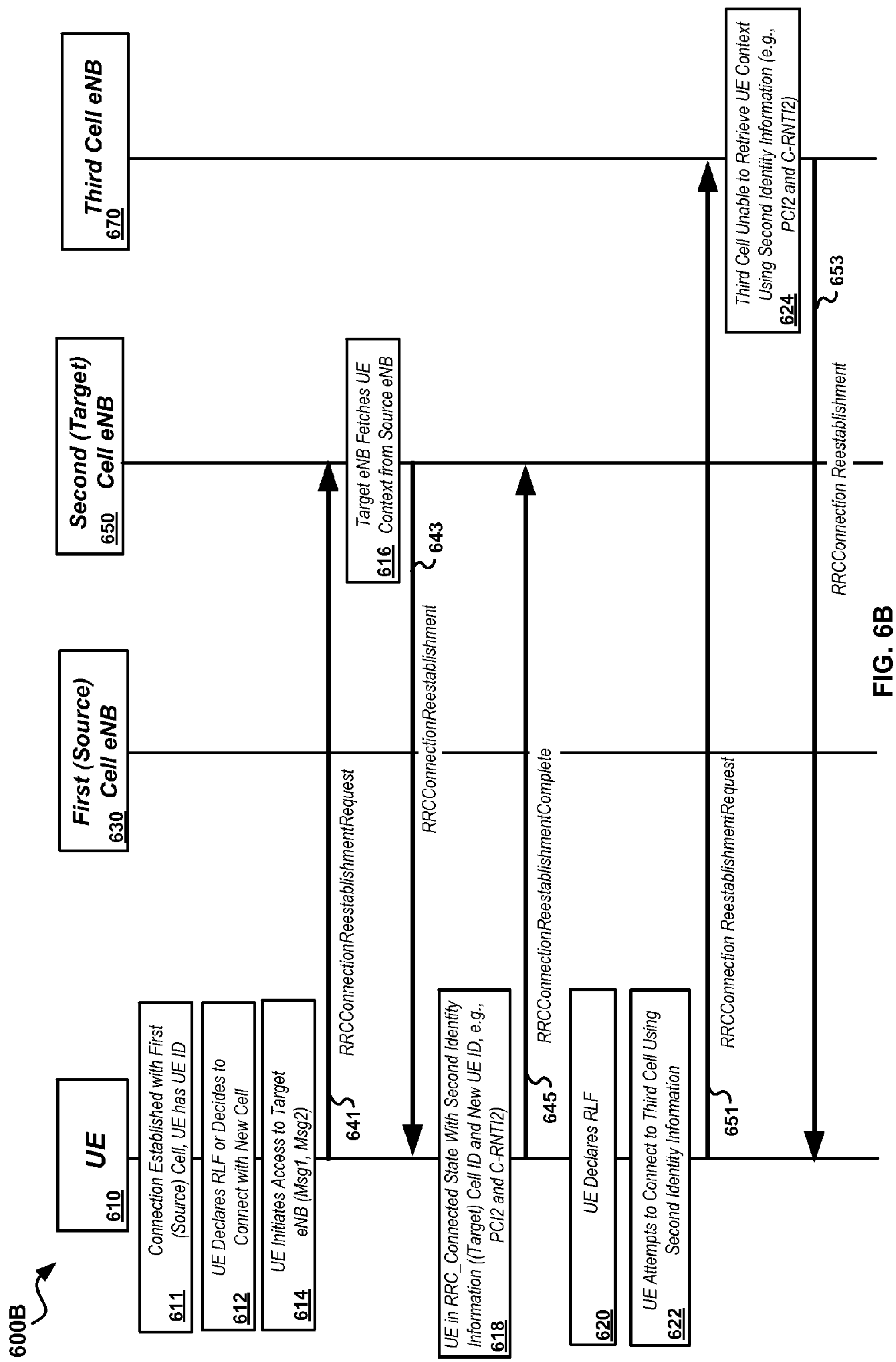

600B
UE 610
First (Source) Cell eNB 630
Second (Target) Cell eNB 650
Third Cell eNB 670
611 Connection Established with First (Source) Cell, UE has UE ID
612 UE Declares RLF or Decides to Connect with New Cell
614 UE Initiates Access to Target eNB (Msg1, Msg2)
641
RRCConnectionReestablishmentRequest
616 Target eNB Fetches UE Context from Source eNB
643
RRCConnectionReestablishment
618 UE in RRC_Connected State With Second Identity Information ((Target) Cell ID and New UE ID, e.g., PCI2 and C-RNTI2)
645
RRCConnectionReestablishmentComplete
620 UE Declares RLF
622 UE Attempts to Connect to Third Cell Using Second Identity Information
651
RRCConnection ReestablishmentRequest
624 Third Cell Unable to Retrieve UE Context Using Second Identity Information (e.g., PCI2 and C-RNTI2)
653
RRCConnection Reestablishment

FIG. 6B

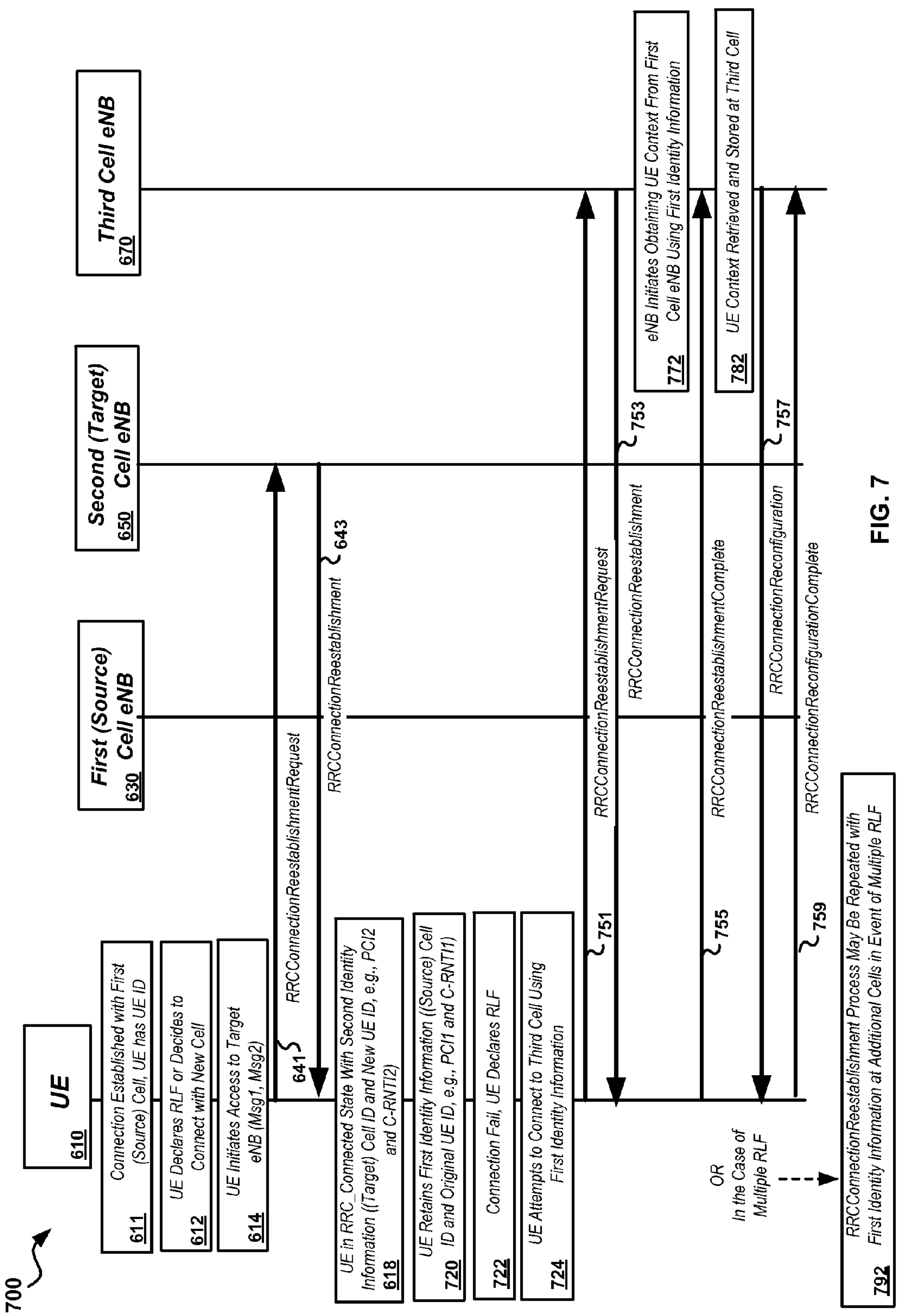

700
UE 610
First (Source) Cell eNB 630
Second (Target) Cell eNB 650
Third Cell eNB 670
611 Connection Established with First (Source) Cell, UE has UE ID
612 UE Declares RLF or Decides to Connect with New Cell
614 UE Initiates Access to Target eNB (Msg1, Msg2)
RRCConnectionReestablishmentRequest
641
RRCConnectionReestablishment
643
618 UE in RRC_Connected State With Second Identity Information ((Target) Cell ID and New UE ID, e.g., PCI2 and C-RNTI2)
720 UE Retains First Identity Information ((Source) Cell ID and Original UE ID, e.g., PCI1 and C-RNTI1)
722 Connection Fail, UE Declares RLF
724 UE Attempts to Connect to Third Cell Using First Identity Information
RRCConnectionReestablishmentRequest
751
RRCConnectionReestablishment
753
772 eNB Initiates Obtaining UE Context From First Cell eNB Using First Identity Information
RRCConnectionReestablishmentComplete
755
782 UE Context Retrieved and Stored at Third Cell
RRCConnectionReconfiguration
757
RRCConnectionReconfigurationComplete
759
OR In the Case of Multiple RLF
792 RRCConnectionReestablishment Process May Be Repeated with First Identity Information at Additional Cells in Event of Multiple RLF

FIG. 7

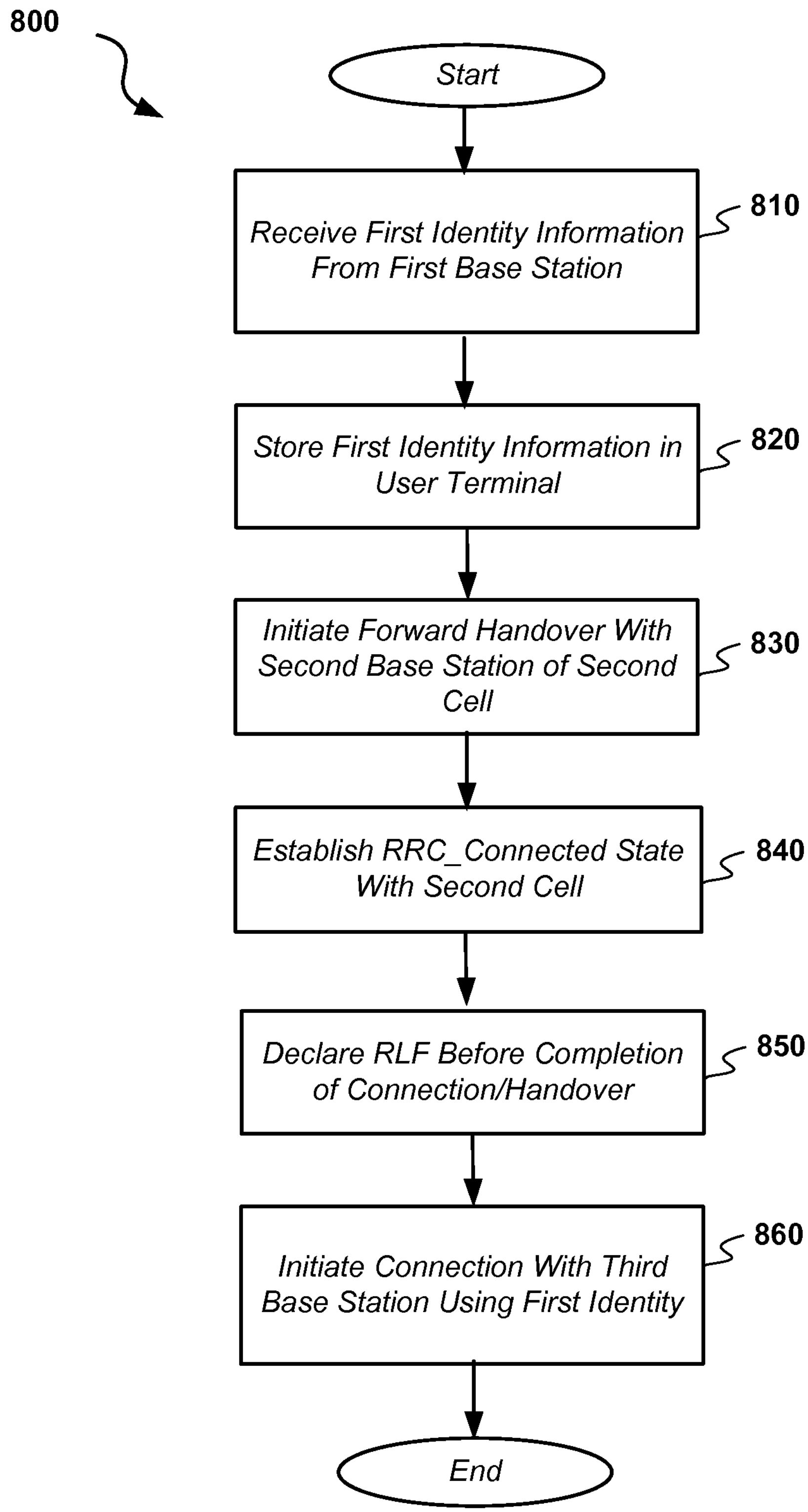

800
Start
Receive First Identity Information From First Base Station
810
Store First Identity Information in User Terminal
820
Initiate Forward Handover With Second Base Station of Second Cell
830
Establish RRC_Connected State With Second Cell
840
Declare RLF Before Completion of Connection/Handover
850
Initiate Connection With Third Base Station Using First Identity
860
End

FIG. 8

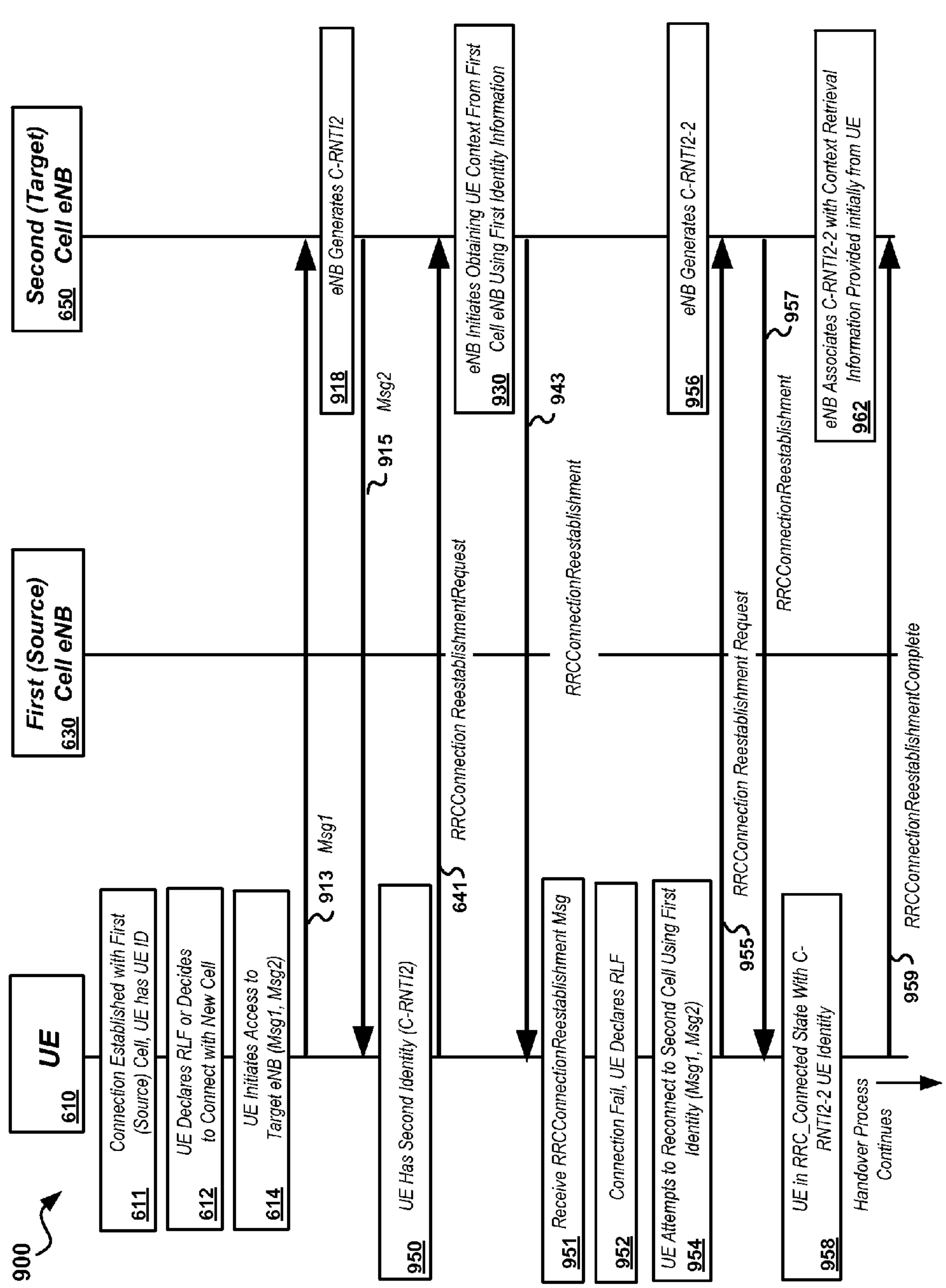

900
UE 610
First (Source) Cell eNB 630
Second (Target) Cell eNB 650
611 Connection Established with First (Source) Cell, UE has UE ID
612 UE Declares RLF or Decides to Connect with New Cell
614 UE Initiates Access to Target eNB (Msg1, Msg2)
913 Msg1
918 eNB Generates C-RNTI2
915 Msg2
950 UE Has Second Identity (C-RNTI2)
641 RRCConnection ReestablishmentRequest
930 eNB Initiates Obtaining UE Context From First Cell eNB Using First Identity Information
943 RRCConnectionReestablishment
951 Receive RRCConnectionReestablishment Msg
952 Connection Fail, UE Declares RLF
954 UE Attempts to Reconnect to Second Cell Using First Identity (Msg1, Msg2)
956 eNB Generates C-RNTI2-2
955 RRCConnection Reestablishment Request
957 RRCConnectionReestablishment
958 UE in RRC_Connected State With C-RNTI2-2 UE Identity
962 eNB Associates C-RNTI2-2 with Context Retrieval Information Provided initially from UE
959 RRCConnectionReestablishmentComplete
Handover Process Continues

FIG. 9

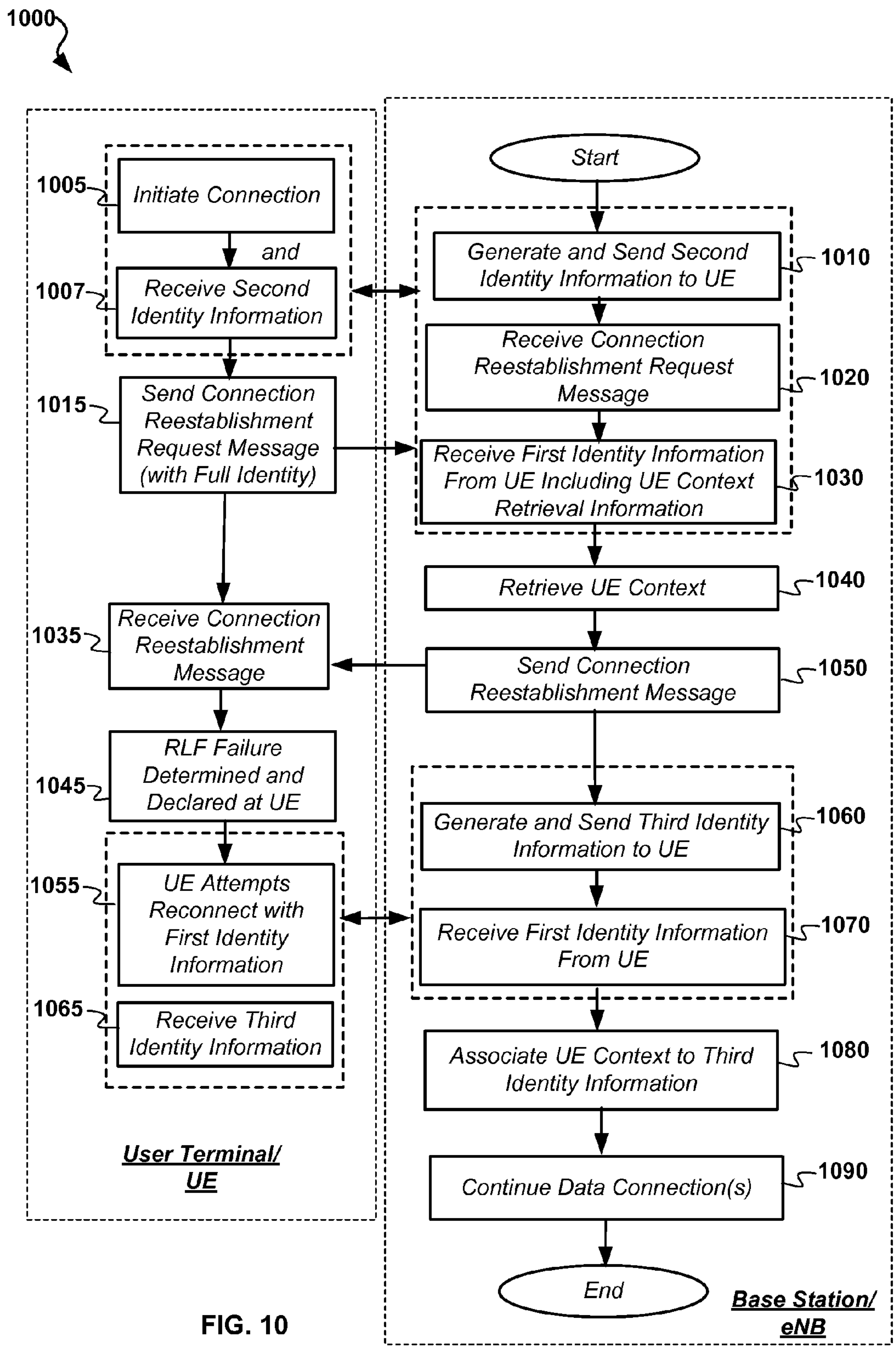

1000
Start
Generate and Send Second Identity Information to UE
1010
Receive Connection Reestablishment Request Message
1020
Receive First Identity Information From UE Including UE Context Retrieval Information
1030
Retrieve UE Context
1040
Send Connection Reestablishment Message
1050
Generate and Send Third Identity Information to UE
1060
Receive First Identity Information From UE
1070
Associate UE Context to Third Identity Information
1080
Continue Data Connection(s)
1090
End
Base Station/ eNB
1005
Initiate Connection
and
1007
Receive Second Identity Information
1015
Send Connection Reestablishment Request Message (with Full Identity)
1035
Receive Connection Reestablishment Message
1045
RLF Failure Determined and Declared at UE
1055
UE Attempts Reconnect with First Identity Information
1065
Receive Third Identity Information
User Terminal/ UE

FIG. 10

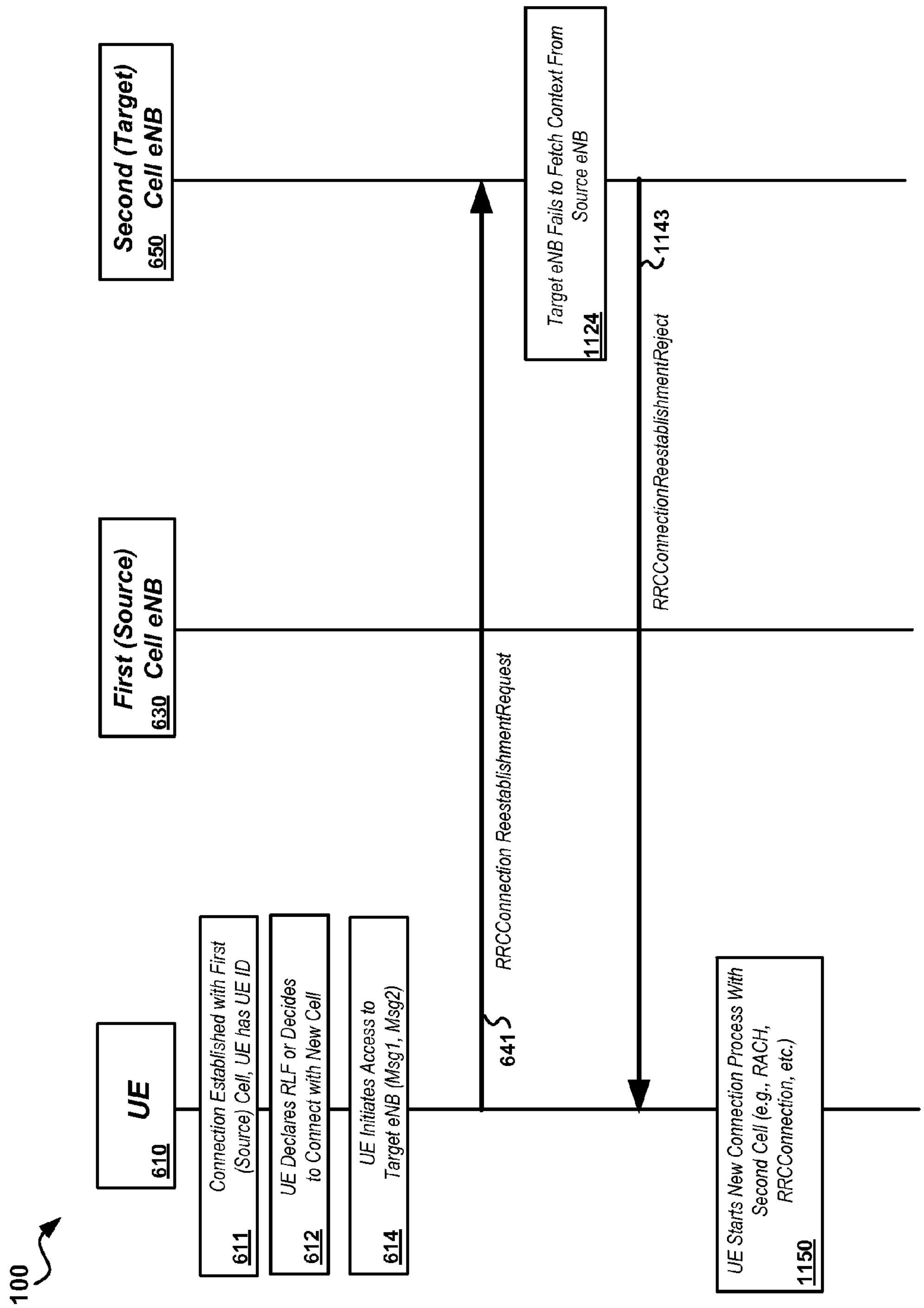

1100
UE
610
First (Source) Cell eNB
630
Second (Target) Cell eNB
650
Connection Established with First (Source) Cell, UE has UE ID
611
UE Declares RLF or Decides to Connect with New Cell
612
UE Initiates Access to Target eNB (Msg1, Msg2)
614
RRCConnection ReestablishmentRequest
641
Target eNB Fails to Fetch Context From Source eNB
1124
RRCConnectionReestablishmentReject
1143
UE Starts New Connection Process With Second Cell (e.g., RACH, RRCConnection, etc.)
1150

FIG. 11

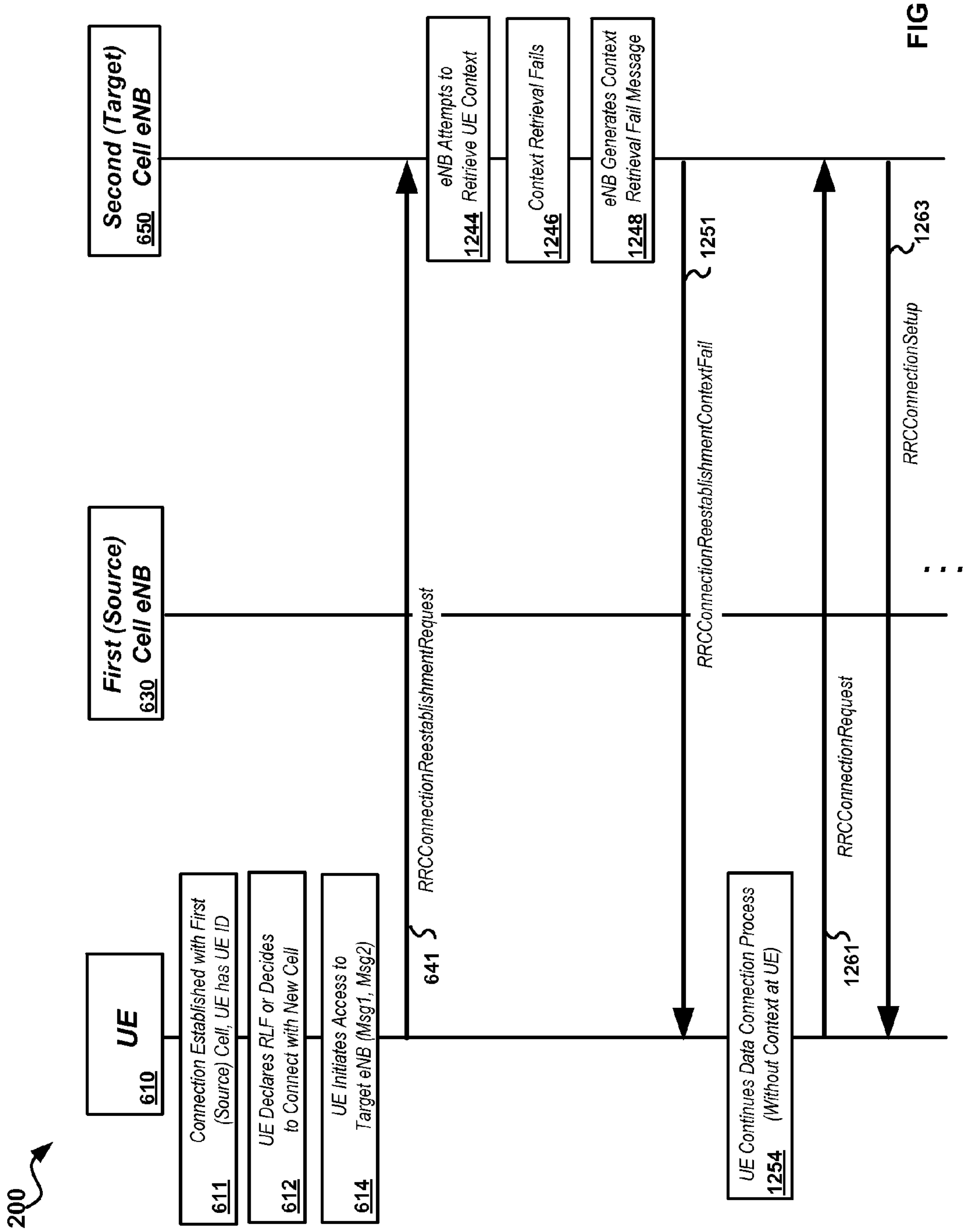

1200
UE
610
First (Source) Cell eNB
630
Second (Target) Cell eNB
650
611 Connection Established with First (Source) Cell, UE has UE ID
612 UE Declares RLF or Decides to Connect with New Cell
614 UE Initiates Access to Target eNB (Msg1, Msg2)
641
RRCConnectionReestablishmentRequest
1244 eNB Attempts to Retrieve UE Context
1246 Context Retrieval Fails
1248 eNB Generates Context Retrieval Fail Message
1251
RRCConnectionReestablishmentContextFail
1254 UE Continues Data Connection Process (Without Context at UE)
1261
RRCConnectionRequest
1263
RRCConnectionSetup
. . .

FIG. 12

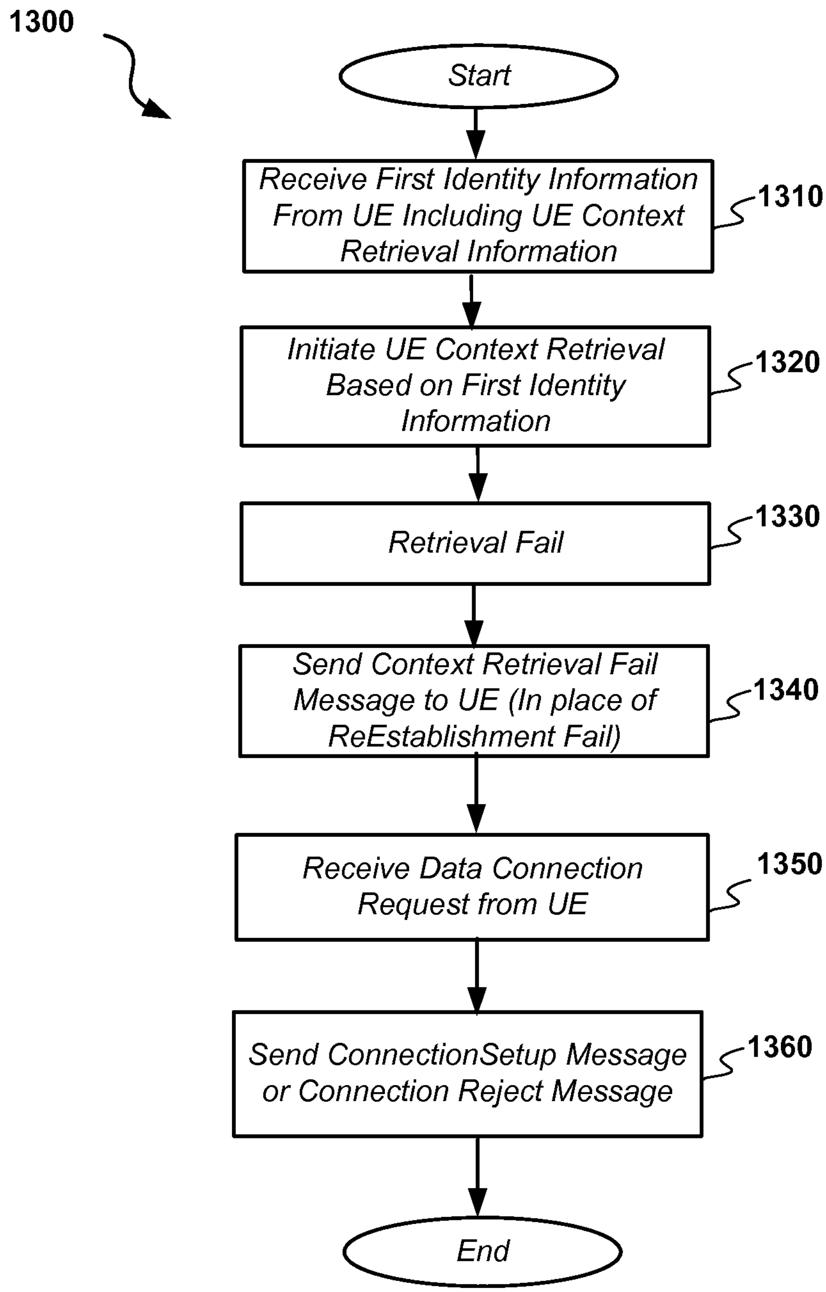

1300
Start
Receive First Identity Information From UE Including UE Context Retrieval Information
1310
Initiate UE Context Retrieval Based on First Identity Information
1320
Retrieval Fail
1330
Send Context Retrieval Fail Message to UE (In place of ReEstablishment Fail)
1340
Receive Data Connection Request from UE
1350
Send ConnectionSetup Message or Connection Reject Message
1360
End

FIG. 13

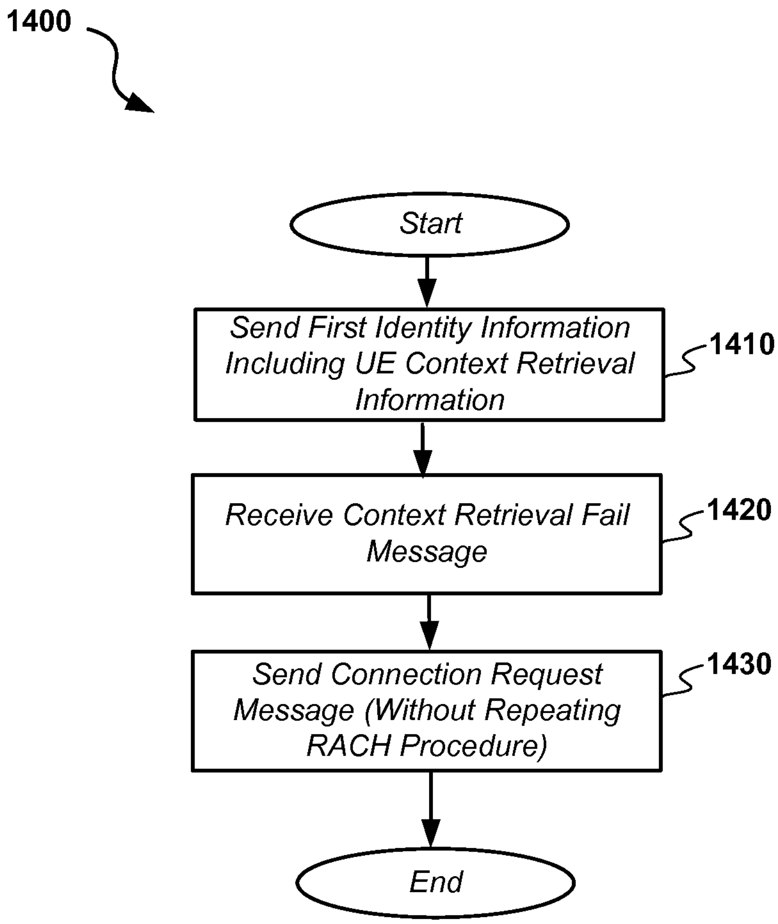

1400
Start
Send First Identity Information Including UE Context Retrieval Information
1410
Receive Context Retrieval Fail Message
1420
Send Connection Request Message (Without Repeating RACH Procedure)
1430
End

FIG. 14

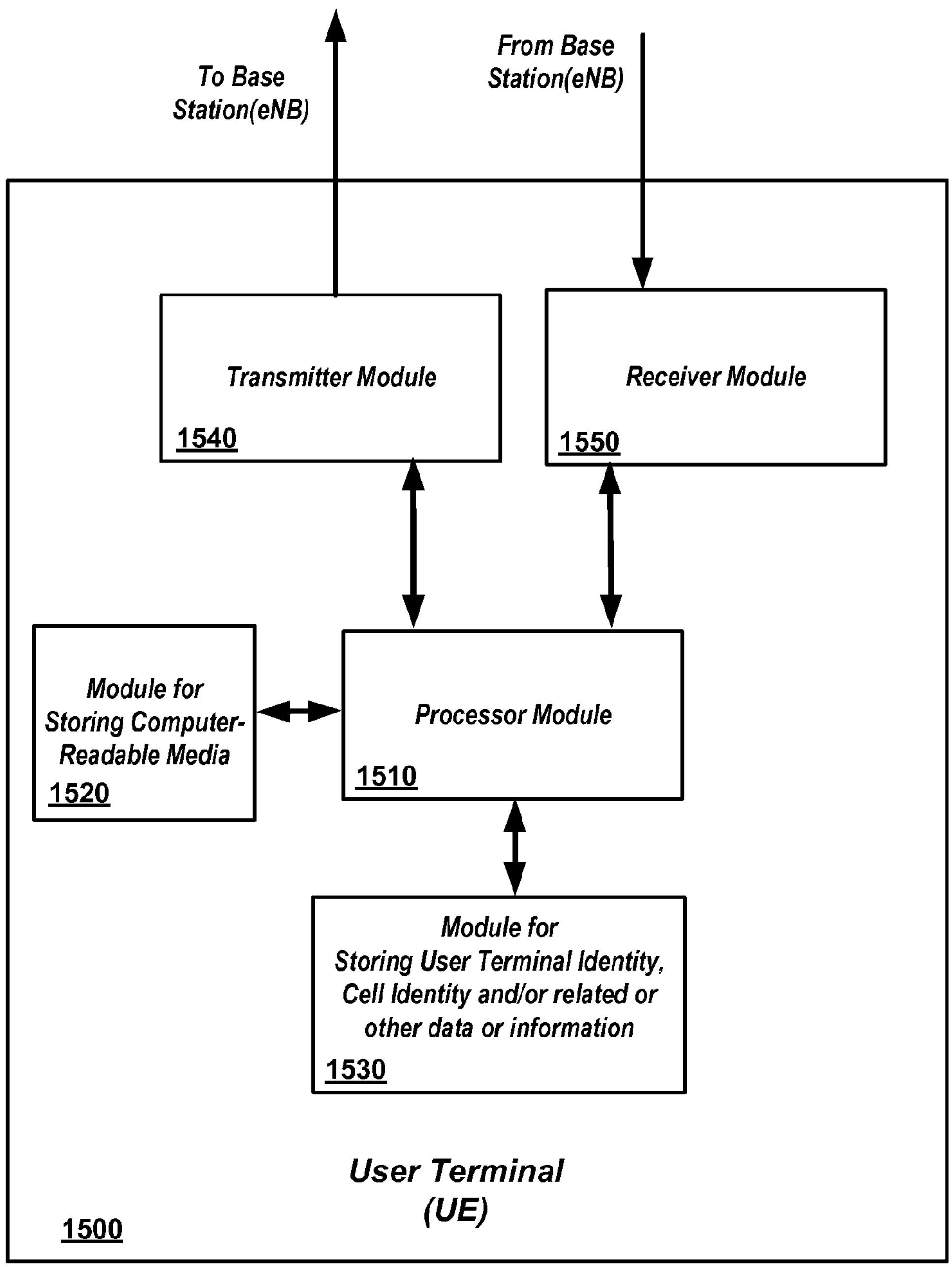
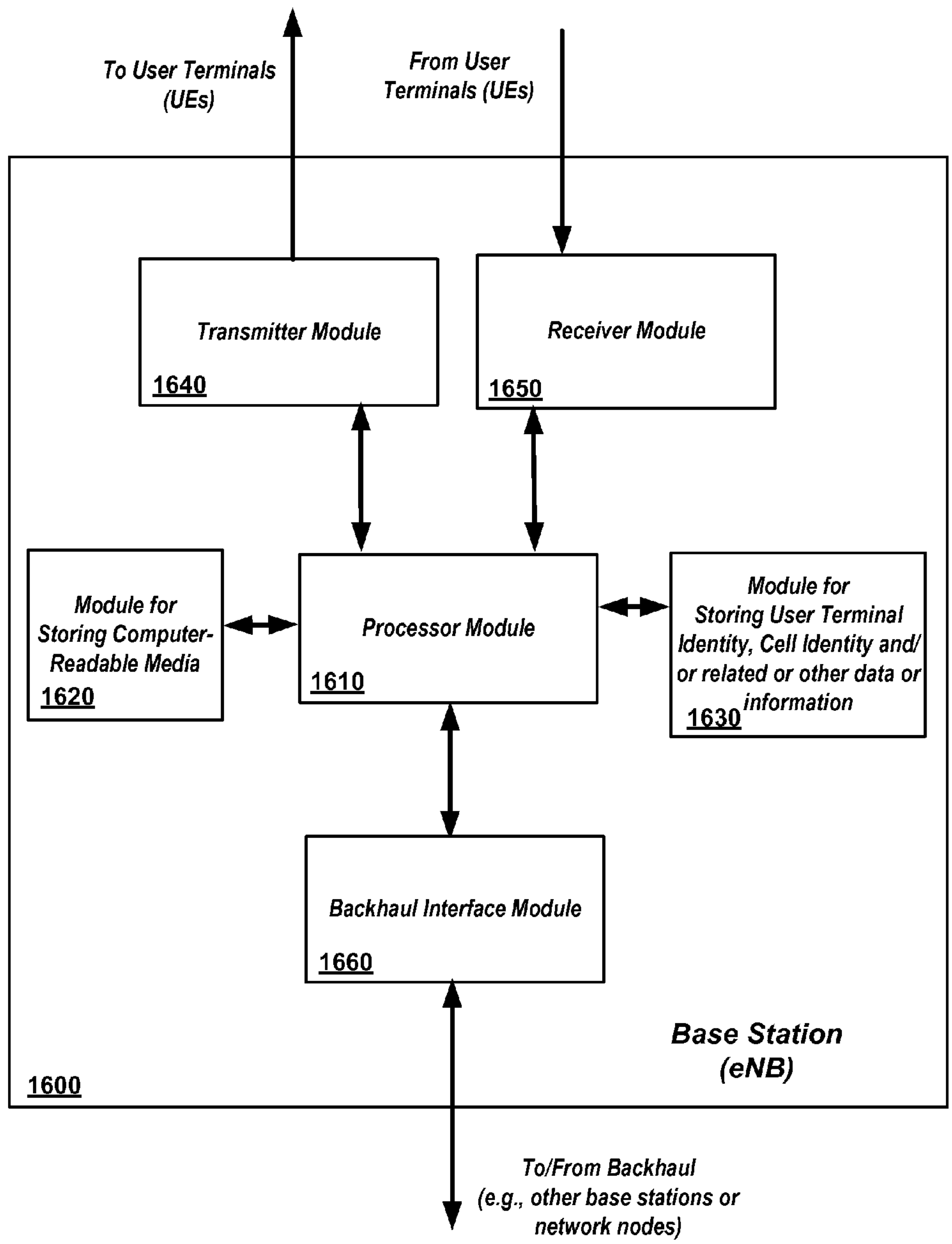

To Base Station(eNB)
From Base Station(eNB)
Transmitter Module
1540
Receiver Module
1550
Module for Storing Computer-Readable Media
1520
Processor Module
1510
Module for Storing User Terminal Identity, Cell Identity and/or related or other data or information
1530
User Terminal (UE)
1500

FIG. 15



To User Terminals (UEs)
From User Terminals (UEs)
Transmitter Module
1640
Receiver Module
1650
Module for Storing Computer-Readable Media
1620
Processor Module
1610
Module for Storing User Terminal Identity, Cell Identity and/or related or other data or information
1630
Backhaul Interface Module
1660
Base Station (eNB)
1600
To/From Backhaul (e.g., other base stations or network nodes)

FIG. 16

METHODS AND APPARATUS FOR FACILITATING ROBUST FORWARD HANDOVER IN LONG TERM EVOLUTION (LTE) COMMUNICATION SYSTEMS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. application Ser. No. 13/028,971, entitled METHOD AND APPARATUS FOR FACILITATING ROBUST FORWARD HANDOVER IN LONG TERM EVOLUTION (LTE) COMMUNICATION SYSTEMS, filed Feb. 16, 2011, which claims priority under 35 U.S.C. §119(e) to U.S. Provisional Patent Application Ser. No. 61/322,660, entitled METHOD AND APPARATUS THAT FACILITATES A ROBUST FORWARD HANDOVER FOR LONG TERM EVOLUTION USER EQUIPMENT, filed on Apr. 9, 2010, and U.S. Provisional Patent Application Ser. No. 61/322,782, entitled METHOD AND APPARATUS THAT FACILITATES A ROBUST FORWARD HANDOVER FOR LONG TERM EVOLUTION USER EQUIPMENT USING USER EQUIPMENT IDENTITIES, filed on Apr. 9, 2010. The content of each of these applications is hereby incorporated by reference herein in its entirety for all purposes.

FIELD

This application is directed generally to wireless communications systems. More particularly, but not exclusively, the application relates to methods and apparatus for facilitating robust forward handovers in wireless communications systems such as LTE communication systems.

BACKGROUND

Wireless communication systems are widely deployed to provide various types of communication content such as voice, data, video and the like, and deployments are likely to increase with introduction of new data oriented systems such as Long Term Evolution (LTE) systems. Wireless communications systems may be multiple-access systems capable of supporting communication with multiple users by sharing the available system resources (e.g., bandwidth and transmit power). Examples of such multiple-access systems include code division multiple access (CDMA) systems, time division multiple access (TDMA) systems, frequency division multiple access (FDMA) systems, 3GPP Long Term Evolution (LTE) systems and other orthogonal frequency division multiple access (OFDMA) systems.

Generally, a wireless multiple-access communication system can simultaneously support communication for multiple wireless terminals (also known as user equipments (UEs), or access terminals (ATs). Each terminal communicates with one or more base stations (also known as access points (APs), Node Bs, Enhanced Node Bs (EnodeBs), or eNBs) via transmissions on forward and reverse links. The forward link (also referred to as a downlink or DL) refers to the communication link from the base stations to the terminals, and the reverse link (also referred to as an uplink or UL) refers to the communication link from the terminals to the base stations. These communication links may be established via a single-input-single-output (SISO), single-input-multiple output (SIMO), multiple-input-single-output (MISO), or multiple-input-multiple-output (MIMO) system.

User terminal devices, such as UEs, are often handed off between base stations and associated cells, for example, when a UE is moving relative to the base stations, or based on other considerations such as base station type, interference, loading or other criteria. In order to provide continuous service, handover procedures are used to effect transfers of UEs between base stations.

SUMMARY

This disclosure relates generally to wireless communications systems. More particularly, but not exclusively, this disclosure relates to systems, methods, and apparatus for facilitating inter-cell connections, such as during a forward handover or radio link failure.

For example, in one aspect, the disclosure relates to a method for facilitating a forward handover in a communications system. The method may include, for example, receiving, at a target base station, a first message from a user terminal indicative of a Random Access Channel (RACH) procedure to initiate access to the target base station. The method may further include sending, from the target base station, a second message to the user terminal to initiate access to the target base station. The method may further include receiving, at the target base station, a connection reestablishment request including first identity information from the user terminal for retrieval of user context information stored at a source base station. The method may further include initiating, at the target base station, retrieval of the user context from the source base station. The method may further include sending, from the target base station, in response to failure to retrieve the user context, a message to the user terminal informing the user terminal to continue the forward handover without performing another RACH procedure. The method may further include receiving, at the target base station, a connection request message from the user terminal.

The first identity information may include, for example, a Physical Cell Identity (PCI) and a Cell Radio Network Temporary Identifier (C-RNTI) associated with the first base station. The first identity information may include an SAE Temporary Mobile Subscriber Identity (S-TMSI)/random number. The connection request message may be, for example, an RRCConnectionRequest message, and the connection request message received without receipt of preceding Random Access Channel (RACH) procedure signaling from the user terminal.

The method may further include sending, from the target base station, a connection setup message. The connection setup message may be an RRCConnectionSetup message.

In another aspect, the disclosure relates to computer program products including computer readable media having instructions for causing a computer to perform the above-described methods.

In another aspect, the disclosure relates to communication apparatus and devices, such as a target base station, configured to perform the above-described methods.

In another aspect, the disclosure relates to communication devices and apparatus, such as a target base station, including means for performing the above-described methods.

Additional aspects, features, and functionality are further described below in conjunction with the appended drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The present application may be more fully appreciated in connection with the following detailed description taken in conjunction with the accompanying drawings, wherein:

FIG. 1 illustrates details of a wireless communications system.

FIG. 2 illustrates details of a wireless communications system having multiple cells.

FIG. 3 illustrates details of an embodiment of a base station and user terminal in a wireless communication system.

FIG. 4A illustrates details of inter-node connections in a wireless communication system.

FIG. 4B illustrates another example of inter-node connections in a wireless communication system without a SON server.

FIG. 5 illustrates details of an example wireless communication system on which a handover procedure may be implemented.

FIG. 6A illustrates a timing diagram for a successful forward handover/radio link failure recovery procedure.

FIG. 6B illustrates a timing diagram for an unsuccessful forward handover/radio link recovery (RLF) procedure where an RLF occurs before establishment of a data connection.

FIG. 7 illustrates a timing diagram for an embodiment of an alternate handover procedure to mitigate the effects of RLF during a forward handover/RLF recovery procedure.

FIG. 8 illustrates details of an embodiment of a process for providing an alternate handover process at a user terminal.

FIG. 9 illustrates details of a timing diagram for an embodiment of an alternate handover procedure to mitigate the effects of RLF during handover.

FIG. 10 illustrates details of an embodiment of a process for providing an alternate handover process at a base station.

FIG. 11 illustrates a timing diagram for an unsuccessful forward handover procedure where a base station is unable to retrieve user terminal context.

FIG. 12 illustrates details of a timing diagram for an embodiment of an alternate forward handover procedure to mitigate the effects of failure to retrieve user terminal context.

FIG. 13 illustrates details of an embodiment of a process for providing an alternate forward handover process at a base station to mitigate the effects of failure to retrieve user terminal context.

FIG. 14 illustrates details of an embodiment of a process for providing an alternate forward handover process at user terminal to mitigate the effects of failure to retrieve user terminal context.

FIG. 15 illustrates details of an embodiment of a user terminal for use in a communication system.

FIG. 16 illustrates details of an embodiment of a base station for use in a communication system.

DETAILED DESCRIPTION

This disclosure relates generally to wireless communication systems and systems and method for facilitating inter-cell connections, such as during a forward handover or radio link failure.

In various embodiments, the techniques and apparatus described herein may be used for wireless communication networks such as Code Division Multiple Access (CDMA) networks, Time Division Multiple Access (TDMA) networks, Frequency Division Multiple Access (FDMA) networks, Orthogonal FDMA (OFDMA) networks, Single-Carrier FDMA (SC-FDMA) networks, LTE networks, as well as other communications networks. As described herein, the terms "networks" and "systems" may be used interchangeably.

A CDMA network may implement a radio technology such as Universal Terrestrial Radio Access (UTRA), cdma2000 and the like. UTRA includes Wideband-CDMA (W-CDMA), Time Division Synchronous CDMA (TD-SCDMA), as well as UTRA/UMTS-TDD 1.28 Mcps Low Chip Rate (LCR). Cdma2000 covers IS-2000, IS-95 and IS-856 standards. A TDMA network may implement a radio technology such as Global System for Mobile Communications (GSM).

An OFDMA network may implement a radio technology such as Evolved UTRA (E-UTRA), IEEE 802.11, IEEE 802.16, IEEE 802.20, Flash-OFDM and the like. UTRA, E-UTRA, and GSM are part of Universal Mobile Telecommunication System (UMTS). In particular, Long Term Evolution (LTE) is a release of UMTS that uses E-UTRA. UTRA, E-UTRA, GSM, UMTS and LTE are described in documents provided from an organization named "3rd Generation Partnership Project" (3GPP), and cdma2000 is described in documents from an organization named "3rd Generation Partnership Project 2" (3GPP2). These various radio technologies and standards are known or are being developed in the art. For example, the 3rd Generation Partnership Project (3GPP) is a collaboration between groups of telecommunications associations that aims to define a globally applicable third generation (3G) mobile phone specification. 3GPP Long Term Evolution (LTE) is a 3GPP project aimed at improving the Universal Mobile Telecommunications System (UMTS) mobile phone standard. The 3GPP may define specifications for the next generation of mobile networks, mobile systems, and mobile devices. For clarity, certain aspects of the apparatus and techniques are described below for LTE implementations, and LTE terminology is used in much of the description below; however, the description is not intended to be limited to LTE applications. Accordingly, it will be apparent to one of skill in the art that the apparatus and methods described herein may be applied to various other communications systems and applications.

Logical channels in wireless communications systems may be classified into Control Channels and Traffic Channels. Logical Control Channels may include a Broadcast Control Channel (BCCH) which is a downlink (DL) channel for broadcasting system control information, a Paging Control Channel (PCCH) which is a DL channel that transfers paging information and a Multicast Control Channel (MCCH) which is a point-to-multipoint DL channel used for transmitting Multimedia Broadcast and Multicast Service (MBMS) scheduling and control information for one or several MTCHs. Generally, after establishing a Radio Resource Control (RRC) connection this channel is only used by UEs that receive MBMS. A Dedicated Control Channel (DCCH) is a point-to-point bi-directional channel that transmits dedicated control information and is used by UEs having an RRC connection.

Logical Traffic Channels may include a Dedicated Traffic Channel (DTCH) which is point-to-point bi-directional channel, dedicated to one UE, for the transfer of user information, and a Multicast Traffic Channel (MTCH) for Point-to-multipoint DL channel for transmitting traffic data.

Transport Channels may be classified into downlink (DL) and uplink (UL) Transport Channels. DL Transport Channels may include a Broadcast Channel (BCH), Downlink Shared Data Channel (DL-SDCH) and a Paging Channel (PCH). The UL Transport Channels may include a Random Access Channel (RACH), a Request Channel (REQCH), an Uplink Shared Data Channel (UL-SDCH) and a plurality of PHY channels. The PHY channels may include a set of DL channels and UL channels.

In addition, the DL PHY channels may include the following:

Common Pilot Channel (CPICH)
Synchronization Channel (SCH)
Common Control Channel (CCCH)
Shared DL Control Channel (SDCCH)
Multicast Control Channel (MCCH)
Shared UL Assignment Channel (SUACH)
Acknowledgement Channel (ACKCH)
DL Physical Shared Data Channel (DL-PSDCH)
UL Power Control Channel (UPCCH)
Paging Indicator Channel (PICH)
Load Indicator Channel (LICH)

The UL PHY Channels may include the following:

Physical Random Access Channel (PRACH)
Channel Quality Indicator Channel (CQICH)
Acknowledgement Channel (ACKCH)
Antenna Subset Indicator Channel (ASICH)
Shared Request Channel (SREQCH)
UL Physical Shared Data Channel (UL-PSDCH)
Broadband Pilot Channel (BPICH)

The word "exemplary" is used herein to mean "serving as an example, instance, or illustration." Any aspect and/or embodiment described herein as "exemplary" is not necessarily to be construed as preferred or advantageous over other aspects and/or embodiments.

For purposes of explanation of various aspects and/or embodiments, the following terminology and abbreviations may be used herein:

AM	Acknowledged Mode
AMD	Acknowledged Mode Data
ARQ	Automatic Repeat Request
BCCH	Broadcast Control CHannel
BCH	Broadcast CHannel
C-	Control-
CCCH	Common Control CHannel
CCH	Control CHannel
CCTrCH	Coded Composite Transport Channel
CP	Cyclic Prefix
CRC	Cyclic Redundancy Check
CTCH	Common Traffic CHannel
DCCH	Dedicated Control CHannel
DCH	Dedicated CHannel
DL	DownLink
DSCH	Downlink Shared CHannel
DTCH	Dedicated Traffic CHannel
FACH	Forward link Access CHannel
FDD	Frequency Division Duplex
GERAN	GSM Radio Access Network
L1	Layer 1 (physical layer)
L2	Layer 2 (data link layer)
L3	Layer 3 (network layer)
LI	Length Indicator
LSB	Least Significant Bit
MAC	Medium Access Control
MBMS	Multmedia Broadcast Multicast Service
MCCH	MBMS point-to-multipoint Control CHannel
MRW	Move Receiving Window
MSB	Most Significant Bit
MSCH	MBMS point-to-multipoint Scheduling CHannel
MTCH	MBMS point-to-multipoint Traffic CHannel
PCCH	Paging Control CHannel
PCH	Paging CHannel
PDU	Protocol Data Unit
PHY	PHYsical layer
PhyCH	Physical CHannels
RACH	Random Access CHannel
RLC	Radio Link Control
RRC	Radio Resource Control
SAP	Service Access Point
SDU	Service Data Unit
SN	Sequence Number

-continued

SUFI	SUper FIeld
TCH	Traffic CHannel
TDD	Time Division Duplex
TFI	Transport Format Indicator
TM	Transparent Mode
TMD	Transparent Mode Data
TTI	Transmission Time Interval
U-	User-
UE	User Equipment
UL	UpLink
UM	Unacknowledged Mode
UMD	Unacknowledged Mode Data
UMTS	Universal Mobile Telecommunications System
UTRA	UMTS Terrestrial Radio Access
UTRAN	UMTS Terrestrial Radio Access Network
MBSFN	Multicast broadcast over a single frequency network
MCE	MBMS coordinating entity
MCH	Multicast channel
DL-SCH	Downlink shared channel
MSCH	MBMS control channel
PDCCH	Physical downlink control channel
PDSCH	Physical downlink shared channel

A MIMO system employs multiple (N_T) transmit antennas and multiple (N_R) receive antennas for data transmission. A MIMO channel formed by the N_T transmit and N_R receive antennas may be decomposed into N_S independent channels, which are also referred to as spatial channels. The maximum spatial multiplexing N_S if a linear receiver is used is $\min(N_T, N_R)$, with each of the N_S independent channels corresponding to a dimension. This provides an N_S increase in spectral efficiency. A MIMO system can provide improved performance (e.g., higher throughput and/or greater reliability) if the additional dimensionalities created by the multiple transmit and receive antennas are utilized. The spatial dimension may be described in terms of a rank.

MIMO systems support time division duplex (TDD) and frequency division duplex (FDD) implementations. In a TDD system, the forward and reverse link transmissions use the same frequency regions so that the reciprocity principle allows the estimation of the forward link channel from the reverse link channel. This enables the access point to extract transmit beamforming gain on the forward link when multiple antennas are available at the access point.

System designs may support various time-frequency reference signals for the downlink and uplink to facilitate beamforming and other functions. A reference signal is a signal generated based on known data and may also be referred to as a pilot, preamble, training signal, sounding signal and the like. A reference signal may be used by a receiver for various purposes such as channel estimation, coherent demodulation, channel quality measurement, signal strength measurement, and the like. MIMO systems using multiple antennas generally provide for coordination of sending of reference signals between antennas, however, LTE systems do not in general provide for coordination of sending of reference signals from multiple base stations or eNBs.

The 3GPP Specification 36.211 defines in Section 5.5 particular reference signals for demodulation, associated with transmission of PUSCH or PUCCH, as well as sounding, which is not associated with transmission of PUSCH or PUCCH. For example, Table 1 lists some reference signals for LTE implementations that may be transmitted on the downlink and uplink and provides a short description for each reference signal. A cell-specific reference signal may also be referred to as a common pilot, a broadband pilot and the like. A UE-specific reference signal may also be referred to as a dedicated reference signal.

TABLE 1

Link	Reference Signal	Description
Downlink	Cell Specific Reference Signal	Reference signal sent by a Node B and used by the UEs for channel estimation and channel quality measurement.
Downlink	UE Specific Reference Signal	Reference signal sent by a Node B to a specific UE and used for demodulation of a downlink transmission from the Node B.
Uplink	Sounding Reference Signal	Reference signal sent by a UE and used by a Node B for channel estimation and channel quality measurement.
Uplink	Demodulation Reference Signal	Reference signal sent by a UE and used by a Node B for demodulation of an uplink transmission from the UE.

In some implementations a system may utilize time division duplexing (TDD). For TDD, the downlink and uplink share the same frequency spectrum or channel, and downlink and uplink transmissions are sent on the same frequency spectrum. The downlink channel response may thus be correlated with the uplink channel response. A reciprocity principle may allow a downlink channel to be estimated based on transmissions sent via the uplink. These uplink transmissions may be reference signals or uplink control channels (which may be used as reference symbols after demodulation). The uplink transmissions may allow for estimation of a space-selective channel via multiple antennas.

In LTE implementations orthogonal frequency division multiplexing is used for the downlink—that is, from a base station, access point or eNodeB (eNB) to a terminal or UE. Use of OFDM meets the LTE requirement for spectrum flexibility and enables cost-efficient solutions for very wide carriers with high peak rates, and is a well-established technology, for example OFDM is used in standards such as IEEE 802.11a/g, 802.16, HIPERLAN-2, Digital Video Broadcasting (DVB), and Digital Audio Broadcasting (DAB).

Time frequency physical resource blocks (also denoted herein as resource blocks or "RBs" for brevity) may be defined in OFDM systems as groups of transport carriers (e.g. sub-carriers) or intervals that are assigned to transport data. The RBs are defined over a time and frequency period. Resource blocks include time-frequency resource elements (also denoted here in as resource elements or "REs" for brevity), which may be defined by indices of time and frequency in a slot. Additional details of LTE RBs and REs are described in, for example, 3GPP Specification TS 36.211.

UMTS LTE may support scalable carrier bandwidths from 20 MHz down to 1.4 MHZ. In LTE, an RB is defined as 12 sub-carriers when the sub-carrier bandwidth is 15 kHz, or 24 sub-carriers when the sub-carrier bandwidth is 7.5 kHz. In an exemplary implementation, in the time domain a radio frame may be defined to be 10 ms long and include 10 subframes of 1 millisecond (ms) each. Every sub frame consists of 2 slots, where each slot is 0.5 ms. The subcarrier spacing in the frequency domain in this case is 15 kHz. Twelve of these subcarriers together (per slot) constitute an RB, so in this implementation one resource block occupies a channel bandwidth of 180 kHz. 6 Resource blocks occupy a channel bandwidth of 1.4 MHz and 100 resource blocks fit in a channel bandwidth of 20 MHz.

In the downlink there are typically a number of physical channels as described above. In particular, the physical downlink control channel (PDCCH) is used for sending control information, the physical hybrid ARQ indicator channel (PHICH) for sending ACK/NACK, the physical control format indicator channel (PCFICH) for specifying the number of control symbols, the Physical Downlink Shared Channel (PDSCH) for data transmission, the Physical Multicast Channel (PMCH) for broadcast transmission using a Single Frequency Network (SFN), and the Physical Broadcast Channel (PBCH) for sending important system information within a cell. Supported modulation formats on the PDSCH in LTE include QPSK, 16QAM and 64QAM. Various modulation and coding schemes are defined for the various channels in the 3GPP specification.

In the uplink there are typically three physical channels. The Physical Random Access Channel (PRACH) is used for initial access and data transmission. When the UE is not uplink synchronized, data is sent on the Physical Uplink Shared Channel (PUSCH). If there is no data to be transmitted on the uplink for a UE, control information is transmitted on the Physical Uplink Control Channel (PUCCH). Supported modulation formats on the uplink data channel include QPSK, 16QAM and 64QAM.

If virtual MIMO/spatial division multiple access (SDMA) is introduced the data rate in the uplink direction can be increased depending on the number of antennas at the base station. With this technology more than one mobile device can reuse the same resources. For MIMO operation, a distinction is made between single user MIMO, for enhancing one user's data throughput, and multi user MIMO for enhancing the cell throughput.

In 3GPP LTE, a mobile station or device may be referred to as a "terminal," "user device," or "user equipment" (UE). A base station may be referred to as an evolved NodeB or eNB. A semi-autonomous base station may be referred to as a home eNB or HeNB. An HeNB may thus be one example of an eNB. The HeNB and/or the coverage area of an HeNB may be referred to as a femtocell, an HeNB cell or a closed subscriber group (CSG) cell (where access is restricted).

Various other aspects and features of the disclosure are further described below. It should be apparent that the teachings herein may be embodied in a wide variety of forms and that any specific structure, function, or both being disclosed herein is merely representative. Based on the teachings herein one skilled in the art should appreciate that an aspect disclosed herein may be implemented independently of any other aspects and that two or more of these aspects may be combined in various ways. For example, an apparatus may be implemented or a method may be practiced using any number of the aspects set forth herein. In addition, such an apparatus may be implemented or such a method may be practiced using other structure, functionality, or structure and functionality in addition to or other than one or more of the aspects set forth herein. Furthermore, an aspect may comprise at least one element of a claim.

FIG. **1** illustrates details of an implementation of a multiple access wireless communication system, which may be an LTE system, on which aspects as further described subsequently may be implemented. A base station or evolved NodeB (eNB) **100** (also know as an access point or AP) may include multiple antenna groups, one including **104** and **106**, another including **108** and **110**, and an additional one including **112** and **114**. In FIG. **1**, only two antennas are shown for each antenna group, however, more or fewer antennas may be utilized for each antenna group. The antennas of base station **100** may define a coverage area of a cell associated with the base station.

A user terminal or user equipment (UE) **116** (also known as an access terminal or AT) may be within the cell coverage area and may be in communication with antennas **112** and **114**, where antennas **112** and **114** transmit information to UE **116** over forward link (also known as a downlink or DL) **120** and receive information from UE **116** over a reverse link (also known as an uplink or UL) **118**. A second UE **122** (and/or additional terminals or UEs not shown) may be in communication with other antennas, such as antennas **106** and **108**, where antennas **106** and **108** may transmit information to UE **122** over forward link **126** and receive information from UE **122** over reverse link **124**. Other antennas, such as antenna **104** (and/or other antennas not shown) may be used to communicate between UES **116**, **122**, and/or other UE or wireless network nodes (not shown).

In a frequency division duplex (FDD) system, communication links **118**, **120**, **124** and **126** use different frequencies for communication. For example, forward link **120** may use a different frequency than that used by reverse link **118**. In a time division duplex (TDD) system, downlinks and uplinks may share the same spectrum.

Each group of antennas and/or the area in which they are designed to communicate is often referred to as a sector of the base station, and may be associated with sector coverage areas, which may be sub-areas of the base station cell coverage area. Antenna groups may each be designed to communicate to UEs in a sector of the cell area covered by eNB **100**. In communication over forward links **120** and **126**, the transmitting antennas of eNB **100** may utilize beam-forming in order to improve the signal-to-noise ratio of forward links for the different access terminals **116** and **122**. Also, an eNB may use beam-forming to transmit to UEs scattered randomly through its coverage area, which may cause less interference to UEs in neighboring cells than an eNB transmitting through a single antenna to all its UEs.

An eNB, such as eNB **100**, may be a fixed station used for communicating with the UEs and may also be referred to as an access point, a Node B, or some other equivalent terminology. In some system configurations, such as heterogeneous networks, the base station or eNB may be one of a variety of types and/or power levels. For example, the eNB may be associated with a macrocell, femtocell, picocell, and/or other type of cell. The eNB may be one of a range of different power levels, such as one of a type of macrocell eNB having any of a range of power levels.

A user terminal or UE may also be denoted as an access terminal, AT, user equipment, wireless communication device, terminal, or some other equivalent terminology. A user terminal may be implemented in the form of a wireless handset, computer or wireless module or device for use with a computer, personal digital assistant (PDA), tablet computer or device, or via any other similar or equivalent device or system.

Attention is now directed to FIG. **2**, which illustrates details of a wireless communication network **200**, which may be an LTE network. Wireless network **200** may include a number of base stations or evolved Node Bs (eNBs) as well as other network entities. An eNB may be a base station that communicates with user terminals or UEs and may also be referred to as Node B, access point, AP, etc. Each base station or eNB may provide communication coverage for a particular geographic coverage area and/or time and/or frequency-multiplexed coverage area.

As shown in FIG. **2**, example communication network **200** includes cells **202**, **204**, and **206**, which each have associated base stations or eNBs **242**, **244**, and **246**, respectively. While cells **202**, **204**, and **206** are shown adjacent to each other, the coverage area of these cells and associated eNBs may overlap and/or be contiguous with each other. For example, an eNB, such as eNBs **242**, **244**, and **246** may provide communication coverage for a macro cell, a picocell, a femtocell, and/or other types of cell. A macrocell may cover a relatively large geographic area (e.g., several kilometers in radius) and may allow unrestricted access by UEs with service subscription. A picocell may cover a relatively small geographic area, may overlap with one or more macrocells, and/or may allow unrestricted access by UEs with service subscription. Likewise, a femtocell may cover a relatively small geographic area (e.g., a home), may overlap with a macrocell and/or picocell, and/or may allow restricted access only to UEs having association with the femtocell, e.g., UEs for users in the home, UEs for users subscribing to a special service plan, etc. An eNB for a macrocell may be referred to as a macro eNB or macro base station or macrocell node. An eNB for a picocell may be referred to as a pico eNB, pico base station or picocell node. An eNB for a femtocell may be referred to as a femto eNB, home eNB, femto base station or femtocell node.

A backhaul/network controller element **250** may couple to a set of eNBs and provide coordination and control for these eNBs. Network controller **250** may be a single network entity or a collection of network entities. Network controller **250** may facilitate communications with eNBs **242**, **244**, and **246** via a backhaul connection and/or with a core network (CN) function. eNBs **242**, **244**, and **246** may also communicate with one another, e.g., directly or indirectly via wireless or wireline backhaul, such as, for example, as shown in FIGS. **4**A and **4**B.

In some implementations, wireless network **200** may be a homogeneous network that includes only macro base stations or eNBs. Wireless network **200** may also be a heterogeneous network or hetnet that includes eNBs of different types, e.g., macro eNBs, pico eNBs, femto eNBs, relay nodes (RNs), etc. These different types of eNBs may have different transmit power levels, different coverage areas, and different impact on interference in wireless network **200**.

For example, macro eNBs may have a high transmit power level (e.g., 20 Watts) whereas pico eNBs, femto eNBs, and relays may have a lower transmit power level (e.g., 1 Watt). The various techniques and aspects described herein may be used in different implementations for homogeneous and heterogeneous networks.

Network **200** may include one or more user terminals or UEs. For example, network **200** may include UEs **230**, **232**, **234**, **236**, **238** and **240** (and/or other UEs not shown). The various UEs may be dispersed throughout wireless network **200**, and each UE may be stationary, mobile, or both. A UE may also be referred to as a terminal, a mobile station, a subscriber unit, a station, etc. For example, a UE may be a cellular phone, a personal digital assistant (PDA), a wireless modem, a wireless communication device, a handheld device, a laptop computer, a cordless phone, a wireless local loop (WLL) station, a pad or table device, etc. As described previously, a UE may communicate with an eNB via a downlink (DL) and an uplink (UL). The downlink (or forward link) refers to the communication link from the eNB to the UE, and the uplink (or reverse link) refers to the communication link from the UE to the eNB. A UE may be able to communicate with macro eNBs, pico eNBs, femto eNBs, relay nodes, and/or other types of eNBs. In FIG. **2**, a solid line with double arrows indicates desired transmissions between a UE and a serving eNB, which is an eNB designated to serve the UE on the downlink and/or uplink. UEs, such as those shown in FIG. **2**, may create interference with each other and/or may receive interference from the various base stations or eNBs. Alternately, or in addition, UEs may move from a connection with one base station to another base station, such as due to UE mobility, interference, loading, etc. As noted previously, communications between base stations may be done directly and/or in conjunction with a backhaul network. For example, communications between base stations may be done in conjunction with establishing new connections such as during forward handovers, in the event of a radio link failure, or during other events such as cell overloading, transition to other network types, etc. Various aspects related to improving connection transfers and handover performance are described subsequently herein.

Attention is now directed to FIG. **3**, which illustrates a block diagram of an embodiment of base station **310** (i.e., an eNB, HeNB, etc.) and a user terminal **350** (i.e., a UE, terminal, AT etc.) in an example LTE communication system **300**, on which aspects and functionality as described subsequently herein may be implemented. In particular, base station **310** and UE **350** may be configured to perform the connection/handover related procedures described subsequently herein, including in FIG. **6**. eNB **350** and UE **310** may correspond with, for example, the base stations and user terminals shown in FIGS. **1**, **2**, **4**A, **4**B, **5**, and **7**.

Various functions may be performed in the processors and memories as shown in base station **310** (and/or in other components not shown), such as communications with other base stations (not shown) of other cells and/or networks, to transmit and receive signaling from the other base stations and UEs, as well as to provide other functionality as described herein.

For example, UE **350** may include one or more modules to receive signals from base station **310** and/or other base stations (not shown, such as non-serving base stations or base stations of other network types as described previously herein) to access base stations, receive DL signals, determine channel characteristics, perform channel estimates, demodulate received data and generate spatial information, determine power level information, and/or other information associated with base station **310** or other base stations (not shown).

In one embodiment, base station **310** may coordinate with other base stations as described herein to facilitate operations such as forward handovers. This may be done in one or more components (or other components not shown) of base station **310**, such as processors **314**, **330** and memory **332**. Base station **310** may also include a transmit module including one or more components (or other components not shown) of eNB **310**, such as transmit modules **322**. Base station **310** may include an interference cancellation module including one or more components (or other components not shown), such as processors **330**, **342**, demodulator module **340**, and memory **332** to provide functionality such as redirection of served UEs, communication with associated MMEs, or other network nodes, signaling redirection information, PS suspension information, handover and context information, and/or other information such as is described herein.

Base station **310** may include a processor module including one or more components (or other components not shown), such as processors **330**, **314** and memory **332** to perform base station functions as described herein and/or manage transmitter and/or receiver modules, which may be used to communicate with UEs or other nodes, such as other base stations, MMEs, etc. Base station **310** may also include a control module for controlling receiver functionality. Base station **310** may include a network connection module **390** to provide networking with other systems, such as backhaul connections, connections to CN elements, as well as other base stations/eNBs, such as via module **390**, or with other components such as are shown in FIGS. **1**-**2**, and **4**A and **4**B.

Likewise, UE **350** may include a receive module including one or more components of UE **350** (or other components not shown), such as receivers **354**. UE **350** may also include a processor module including one or more components (or other components not shown) of UE **350**, such as processors **360** and **370**, and memory **372**, to perform the processing functions associated with user terminals as described subsequently herein. This may include, for example, initiating new connections/handovers, declaring failures, such as RLF, performing access procedures, etc.

In one embodiment, one or more signals received at UE **350** are processed to receive DL signals and/or extract information such as MIB and SIB information from the DL signals. Additional processing may include estimating channel characteristics, power information, spatial information, and/or other information associated with eNBs, such as base station **310** and/or other base stations, such as Node Bs (not shown), facilitating redirection commands, searching for and locating redirection targets and alternate targets, such as fallback targets, as well as facilitating communicating with other cells or networks and associated nodes, such as base stations or Node Bs of those different networks.

Memory **332** (and/or other memories of base station **310** that are not shown in FIG. **3**) may be used to store computer code for execution on one or more processors, such as processors **314**, **320**, **330**, and **342** (and/or other processors of base station **310** that are not shown) to implement processes associated with the aspects and functionality described herein, and in particular with regard to FIGS. **7**, **8**, **9**, **10**, and **12**-**14**. Likewise, memory **372** (and/or other memories of user terminal **350** that are not shown) may be used to store computer code for execution on one or more processors, such as processors **338**, **360**, and **370** to implement processes associated with the aspects and functionality described herein. The memories may be used, for example, to store information such as context information, cell and user terminal identity information, as well as other information associated with wireless device and system operation.

In operation, at the base station **310**, traffic data for a number of data streams may be provided from a data source **312** to a transmit (TX) data processor **314**, where the data may be processed and transmitted to one or more UEs **350**. In one aspect, each data stream is processed and transmitted over a respective transmitter sub-system (shown as transmitters $\mathbf{322}_1$-$\mathbf{322}_{Nt}$ and antennas $\mathbf{324}_1$-$\mathbf{324}_{Nt}$) of base station **310**. TX data processor **314** receives, formats, codes, and interleaves the traffic data for each data stream based on a particular coding scheme selected for that data stream so as to provide coded data. In particular, base station **310** may be configured to determine a particular reference signal and reference signal pattern and provide a transmit signal including the reference signal and/or beamforming information in the selected pattern.

The coded data for each data stream may be multiplexed with pilot data using OFDM techniques. The pilot data is typically a known data pattern that is processed in a known manner and may be used at the receiver system to estimate the channel response. For example, the pilot data may include a reference signal. Pilot data may be provided to TX data processor **314** as shown in FIG. **3** and multiplexed with the coded data. The multiplexed pilot and coded data for each data stream may then be modulated (i.e., symbol mapped) based on a particular modulation scheme (e.g., BPSK, QSPK, M-PSK, M-QAM, etc.) selected for that data stream so as to provide modulation symbols, and the data and pilot may be modulated using different modulation schemes. The data rate, coding, and modulation for each data stream may be determined by instructions performed by processor **330** based on instructions stored in memory **332**, or in other memory or instruction storage media of UE **350** (not shown).

The modulation symbols for all data streams may then be provided to a TX MIMO processor **320**, which may further process the modulation symbols (e.g., for OFDM implementation). TX MIMO processor **320** may then provide Nt modulation symbol streams to Nt transmitters (TMTR) $\mathbf{322}_1$ through $\mathbf{322}_{Nt}$. The various symbols may be mapped to associated RBs for transmission.

TX MIMO processor **320** may apply beamforming weights to the symbols of the data streams and corresponding to the one or more antennas from which the symbol is being transmitted. This may be done by using information such as channel estimation information provided by or in conjunction with the reference signals and/or spatial information provided from a network node such as a UE. For example, a beam B=transpose($[b_1\ b_2 \ldots b_{Nt}]$d) composes of a set of weights corresponding to each transmit antenna. Transmitting along a beam corresponds to transmitting a modulation symbol x along all antennas scaled by the beam weight for that antenna; that is, on antenna t the transmitted signal is bt*x. When multiple beams are transmitted, the transmitted signal on one antenna is the sum of the signals corresponding to different beams. This can be expressed mathematically as $B_1x_1+B_2x_2+B_{Ns}x_{Ns}$, where Ns beams are transmitted and x_i is the modulation symbol sent using beam B_i. In various implementations beams could be selected in a number of ways. For example, beams could be selected based on channel feedback from a UE, channel knowledge available at the eNB, or based on information provided from a UE to facilitate interference mitigation, such as with an adjacent macrocell.

Each transmitter sub-system $\mathbf{322}_1$ through $\mathbf{322}_{Nt}$ receives and processes a respective symbol stream to provide one or more analog signals, and further conditions (e.g., amplifies, filters, and upconverts) the analog signals to provide a modulated signal suitable for transmission over the MIMO channel. Nt modulated signals from transmitters $\mathbf{322}_1$ through $\mathbf{322}_{Nt}$ are then transmitted from Nt antennas $\mathbf{324}_1$ through $\mathbf{324}_{Nt}$, respectively.

At UE **350**, the transmitted modulated signals are received by Nr antennas $\mathbf{352}_1$ through $\mathbf{352}_{Nr}$ and the received signal from each antenna **352** is provided to a respective receiver (RCVR) $\mathbf{354}_1$ through $\mathbf{352}_{Nr}$. Each receiver **354** conditions (e.g., filters, amplifies and downconverts) a respective received signal, digitizes the conditioned signal to provide samples, and further processes the samples to provide a corresponding "received" symbol stream.

An RX data processor **360** then receives and processes the Nr received symbol streams from Nr receivers $\mathbf{354}_1$ through $\mathbf{352}_{Nr}$ based on a particular receiver processing technique so as to provide Ns "detected" symbol streams so at to provide estimates of the Ns transmitted symbol streams. The RX data processor **360** then demodulates, deinterleaves, and decodes each detected symbol stream to recover the traffic data for the data stream. The processing by RX data processor **360** is typically complementary to that performed by TX MIMO processor **320** and TX data processor **314** in base station **310**.

A processor **370** may periodically determine a precoding matrix. Processor **370** may then formulate a reverse link message that may include a matrix index portion and a rank value portion. In various aspects, the reverse link message may include various types of information regarding the communication link and/or the received data stream. The reverse link message may then be processed by a TX data processor **338**, which may also receive traffic data for a number of data streams from a data source **336** which may then be modulated by a modulator **380**, conditioned by transmitters $\mathbf{354}_1$ through $\mathbf{354}_{Nr}$, and transmitted back to base station **310**. Information transmitted back to base station **310** may include power level and/or spatial information for providing beamforming to mitigate interference from base station **310**.

At base station **310**, the modulated signals from UE **350** are received by antennas **324**, conditioned by receivers **322**, demodulated by a demodulator **340**, and processed by a RX data processor **342** to extract the message transmitted by UE **350**. Processor **330** may then determine which pre-coding matrix to use for determining beamforming weights, and then processes the extracted message.

Attention is now directed to FIG. **4**A, which illustrates details of one example network embodiment **400**A of interconnection between eNBs and other wireless network elements, such as may be used during handovers or for other inter-cell communication and/or coordination. Network **400**A may include a macro-eNB **402** and/or multiple additional eNBs, which may be picocell eNBs **410** (or, for example other macrocell eNBs, femtocell eNBs, etc. not shown). Network **400**A may include an eNB gateway (or other gateway type) **434**, which may be, for example, an HeNB gateway, for scalability reasons.

The macro-eNB **402** and the gateway **434** may each communicate with a pool **440** of mobility management entities (MME) **442** and/or a pool **444** of serving gateways (SGW) **446**. The eNB gateway **434** may appear as a C-plane and a U-plane relay for dedicated S1 connections **436**. An S1 connection **436** may be a logical interface specified as the boundary between an evolved packet core (EPC) and an Evolved Universal Terrestrial Access Network (EUTRAN). As such, it provides an interface to a core network (CN) (not shown) which may be further coupled to other networks.

The eNB gateway **434** may act as a macro-eNB **402** from an EPC point of view. The control plane (C-plane) interface may be an S1-MME and the U-plane interface may be an S1-U. Transfer of information, such as during handover or new connection establishment, may be done by direct communication between eNBs such as those shown in FIG. **4**A, and/or may be done in conjunction with a backhaul network, such as via backhaul interface **250** as shown in FIG. **2**.

The eNB gateway **434** may act towards an eNB **410** as a single EPC node. The eNB gateway **434** may ensure S1-flex connectivity for an eNB **410**. The eNB gateway **434** may provide a 1:n relay functionality such that a single eNB **410** may communicate with n MMEs **442**. The eNB gateway **434** may register towards the pool **440** of MMEs **442** when put into operation via the S1 setup procedure. The eNB gateway **434** may support setup of S1 interfaces **436** with the eNBs **410**.

Network **400**A may also include a self organizing network (SON) server **438**. The SON server **438** may provide automated optimization of a 3GPP LTE network. The SON server **438** may be a key driver for improving operation administration and maintenance (OAM) functions in the network **400**A.

An X2 link **420** may exist between the macro-eNB **402** and the eNB gateway **434**. X2 links **420** may also exist between each of the eNBs **410** connected to a common eNB gateway **434**. The X2 links **420** may be set up based on input from the SON server **438**. An X2 link **420** may convey inter-cell interference coordination (ICIC) information. If an X2 link **420** cannot be established, the S1 link **436** may be used to convey ICIC information. Information may be exchanged using these links, for example, in the case of connection establishment and/or handovers.

Backhaul signaling may be used in communication system **400**A to manage various functionality as described further herein between macro-eNB **402** and eNBs **410**. For example, these connections may be used as further described successively herein to facilitate connection establishment and handovers.

FIG. **4**B illustrates another example embodiment of a network **400**B of eNB interconnection with other eNBs and wireless network elements including a similar configuration of elements as shown in FIG. **4**A. In network **400**B, however, no SON server is included, and macro eNBs, such as eNB **402**, may communicate directly with other eNBs, such as pico eNB **410** (and/or with other base stations that are not shown). While FIGS. **4**A and **4**B are shown for purposes of illustration of example inter-cell connectivity, other configurations for providing connectivity between base stations and other network elements may also be used in various implementations.

As described previously with respect to FIG. **2**, a user terminal or UE may desire to establish a connection with a new base station or eNB, such as, for example, when the UE is moving, declares radio link failure (RLF), or otherwise wishes to establish a connection with a different cell. In performing such a connection, base stations in various cells may communicate to share information, such as context information associated with the UE. This information done via connections such as shown in FIGS. **4**A and **4**B, and may be based on information provided from the UE during connection establishment, such as cell identity and user terminal identity information.

Attention is now directed to FIG. **5**, which illustrates details of a wireless network on which a connection process, such as may be performed during a forward handover, may be effected between cells in a wireless communication system **500**. As shown, communication system **500** includes three cells, denoted as cell **510**, cell **520**, and cell **530**. Each cell includes an associated base station, such as an eNB. For example, base station **512** may be associated with cell **510** and serve one or more user terminals, such as UEs, within the coverage area of cell **510**. Similarly, cells **520** and **530** may have associated base stations **522** and **532**, respectively. It is noted that, while system **500** is shown as including three cells **510**, **520**, and **530**, various other system configurations having different numbers of cells, cell coverage areas, base station types, as well as other configuration elements may also be used consistent with the various aspects of the disclosure. As such, system **500** is shown with three cells in the particularly illustrated configuration for purposes of illustration and not limitation.

One or more of cells **510**, **520**, **530**, and/or other cells (not shown) may be LTE cells within an LTE network. In addition, in some configurations, other cells and associated cell types, such as UTRAN, GSM Radio Access Network (GERAN), etc. (not shown) may be included in system **500**. As described subsequently herein, handovers and associated procedures are illustrated in the context of an LTE system, however, in some cases other wireless network types may also be included as part of the handover process. For example, a terminal initially served by an LTE cell may be handed over to a UTRAN or GERAN network cell, and may subsequently attempt to re-establish communication with the LTE cell or another LTE cell. Other inter-network handover procedures may also be done consistent with various aspects of the disclosure.

One or more user terminals, such as terminal **505**, which may be a user equipment (UE), may be in communication with cells within network **500**. For example, user terminal or UE **505** may initially be in communication with base station **512** in cell **510** via a connection such as connection **514** as shown in FIG. **5**. Connection **514** may include a downlink (DL) between base station **512** and terminal **505** and an uplink (UL) between terminal **505** and base station **512**. While operating in cell **510**, the UE may have an associated UE identity, such as an S-TMSI, C-RNTI & random number (which may be generated by the UE during connection setup), and/or other UE specific identity information. The UE identity may be provided by the base station, such as eNB **512**, which may provide the S-TMSI/C-RNTI. Likewise, the UE may be provided with and store a cell-specific identity, such as a PCI.

In operation, terminal **505** may initially be served by base station **512** of cell **510**, but may wish to establish a connection with another cell and its associated base station or eNB, such as cell **520** and/or cell **530**. For example, in one case, terminal **505** may be a mobile terminal, such as a UE being operated in a vehicle or otherwise in movement, such as via path **508** as shown in FIG. **5**. In this case, terminal **305** may be handed over to another of the base stations, such as when moving out of the coverage area of the first or current cell (e.g., cell **510**) and into the coverage area of a second or target cell (e.g., cell **520**). This may be done as part of a handover procedure. Alternately or in addition, the new connection may be initiated based on other events, such as determination of conditions of radio failure and declaration of radio link failure (RLF) by the terminal, cell loading, etc.

In the case of terminal movement or mobility, terminal **505** may initially be served by base station **512** of cell **510**, but may be moving towards cells **520** and **530**. For example, terminal **505** may initially move into the coverage area of cell **520**, such as via path **508**, and may wish to establish a connection **524** with base station **522** of cell **520**. Based on a connection established between UE **505** and base station **512**, the base station **512** may store context information associated with UE **505**, such as, for example, Data Radio Bearer (DRB) setup information, user subscription information, and/or other information related to the UE. The UE context information may be transferred or moved to another base station of another cell during UE mobility procedures, such as during handovers.

In addition, UE **505** may have stored first identity information associated with cell **510** and base station **512** as described previously. For example, the cell identity may be the Physical Cell Identity (PCI) and the UE identity may be an allocated SAE Temporary Mobile Subscriber Identity (S-TMSI), Cell Radio Network Temporary Identifier (C-RNTI) and/or random number that may be generated by the base station **512**, and/or other UE specific identity information. This first identity information may be denoted for purposes of explanation herein as PCI1 and S-TMS1 or C-RNTI1. However, it will be apparent that other cell and UE-specific identity information (in place of or in addition to PCI, S-TMSI, and/or C-RNTI information) may also be used in various implementations.

In order to effect such an inter-eNB transfer, the UE **505** may begin the process of connecting with base station **522**, such as is defined in the 3GPP Specifications, including 3GPP TS 23.401 and 3GPP TS 36.331. This may be based on a handover request generated by base station **512**, which may be done via inter-cell connectivity such as shown in FIGS. **4**A and **4**B. For example, base station **512** may signal, via backhaul connection **517**, which may be, for example, an S1 or X2 connection, the handover request. Handover related information may be received at base station **522** via an analogous backhaul connection **527**. Additional details of example handover timing are described subsequently with respect to FIG. **6**A and FIG. **6**B.

If the connection process between UE **505** and base station **522** continues to the stage of the UE **505** receiving an RRC-ConnectionRestablishment message from base station **522**, the UE will be in the Radio Resource Control (RRC) connected state (RRC_Connected), and will receive and store second cell identification information (e.g., second cell ID and new UE ID), as well as remove or disregard previous or first cell and UE identities (e.g., first cell ID and UE identification information assigned by the first cell).

However, if an RLF occurs before completion of the forward handover (e.g., the UE **505** fails to complete the connection/handover to base station **522**), the UE **505** may then attempt to connect to a third base station and cell, such as base station **532** in cell **530**, which may be done via connection **534**, or UE **505** may attempt to reconnect to the original cell, such as base station **512** in cell **510**, and/or to another cell (not shown) by performing a cell reselection process. In this case, the UE **505** will then use the information associated with base station **522** (e.g., the second cell ID and UE identities associated with base station **522** provided in msg2) to attempt to perform the subsequent connection/handover, such as to base station **532** via connection **534**.

However, the subsequent forward handover between UE **505** and base station **532** may then fail because the original cell identity and associated context may not be retrievable due to failure to complete the handover to the second cell. This may cause potentially significant service impact as an RRC Connection process (e.g., transmission of an RRCConnection message and subsequent signaling) may need to be performed to reestablish the connection. For example, data buffered in the source eNB can be received by the target eNB and the target eNB will not need to reestablish the context/connection with an associated MME and Gateway. This may result in better performance and/or prevention of data loss. Conversely, if context is lost, buffered data cannot be retrieved and may have to be resent when a new connection is established.

For example, base station **532** may attempt to receive context information from base station **522**, such as via backhaul connection **537**, however, base station **522** will be unable to deliver the context information because it may have deleted the fetched context from the source eNB (e.g., eNB **512**) since the connection may not have been completed. Moreover, in some cases, this failure process can occur multiple times (e.g., multiple radio link failure (RLF) may occur). Subsequent connection attempts may similarly fail due to failure to retain fetched context because the UE may not have completed the connection setup with the eNBs.

For example, FIG. **6**A illustrates a simplified timing diagram of an example handover process **600**A where handover of an authenticated UE between first (source) and second (target) cells is properly completed. In this example, a user terminal or UE **610**, which may correspond to UE **505** of FIG. **5**, is connected at stage **611** and being served by a first base station or eNB **630** of a first cell, which may be, for example, an LTE macrocell, femtocell, picocell, etc. At stage **611**, UE **610** has a stored first or source cell UE identity information (UE ID). eNB **630** may correspond with base station **512** and may be serving the cell **510** as shown in FIG. **5**. eNB **630** may determine that a handover is appropriate, for example, based on reports from the UE **610**, cell loading, mobility information, and/or other similar or related information. For example, eNB **650** may correspond with base station **522** and may be serving cell **520** as shown in FIG. **5**. The second cell will typically be another LTE cell; however, in some implementations, the second cell may be a cell using another radio access technology, such as, for example, a UTRAN, GERAN, or other network type.

At stage **612**, the UE **610** may detect or determine failure conditions and declare RLF and/or otherwise decide to connect with a new cell. At stage **614**, the UE may initiate access to handover target eNB **650**. This may include, for example, sending LTE Msg1 to eNB **650** and receiving Msg2, including second identity information, including a second or target UE ID, from eNB **650**. UE **610** may then send an RRCConnectionReestablishmentRequest message **641** to eNB **650**, which may be followed by transmission of an RRCConnectionReestablishment message **643** (e.g., LTE msg4) from eNB **650**. At stage **616**, the target cell eNB **650** may fetch UE context information from source cell eNB **630**, such as, for example, via connections as shown in FIG. **4**A and FIG. **4**B. Subsequent to receipt of the RRCConnectionReestablishment message **643**, the UE **610** will be in the RRC_Connected stage and will have second identity information assigned by eNB **650**.

The second identity information may include, for example, a PCI associated with the second cell (denoted herein as PCI2 for purposes of explanation) and a second UE identity (denoted herein as C-RNTI2 for purposes of explanation). As such, at stage **618**, the UE will have the second identity information associated with the target eNB **650**, and the handover process may then be continued by sending an RRCConnectionReestablishmentComplete message **645** from UE **610** to the target eNB **650**. Subsequent to transmission of the RRCConnectionReestablishmentComplete message **645**, the enB **650** may send an RRCConnectionReconfiguration message **647**, which may be followed by an RRCCOnnectionReconfigurationComplete message **649** from UE **610**. Subsequent to sending of RRCConnectionReconfigurationComplete message **649**, the handover may be completed successfully at stage **680**. At this point, eNB **650** may resume data transmission to UE **610** using the retrieved context. Various additional aspects and details of this process are further described and illustrated in the 3GPP Specifications, including, for example, 3GPP TS 36.331.

Conversely, FIG. **6**B illustrates a timing diagram **600**B illustrating an example failed handover as described previously with respect to FIG. **5**. In this example, processing may proceed through stage **618** (as shown and described, for example, with respect to FIG. **6**A). A failure may, however, occur after the UE has entered the RRC_Connected state subsequent to receipt of the RRCConnectionReestablishment message **643** and/or transmission of RRCConnectionReestablishmentComplete message **645**. In this case, the UE may detect or determine failure conditions and declare RLF at stage **620**, and then search for and attempt to connect to another cell at stage **622**. For example, the UE may return to the first (source) cell (not show diagrammatically in FIG. **6**B) or may attempt to connect to a third cell and associated base station or eNB **670**, such as by sending another RRCConnectionEstablishmentRequest message **651**.

As currently defined in the 3GPP Specifications, for example, in 3GPP TS 36.331, Section 5.3.7, the UE uses the previous cell identity information (subsequent to establishment of RRC_Connected) during subsequent RRCConnectionReestablishment procedures (e.g., PCI2 and C-RNTI2 from the second cell as provided from eNB **650**). However, the forward handover/RLF recovery process may fail because base station **670** will be unable to retrieve the UE context for UE **610** at stage **624** since it does not have the initial or first identity information associated with the first (source) cell and associated eNB **630** (e.g. first UE ID information, such as S-TMSI1 or PCI1, C-RNTI1, and the initial random number).

In order to address this problem as well as provide other potential advantages, an alternate handover procedure may be performed by a user terminal, such as UE **505**, to facilitate inter-cell handovers/connection establishment. In particular, a UE may maintain first identity information, which may include cell identity information regarding the most recent cell to which the UE was connected and UE specific identity information (e.g., S-TMSI1 or PC1 and C-RNTI1 as described previously with respect to FIGS. **6**A and **6**B). Then, when the UE seeks to connect to a second base station, such as during a forward handover or RLF event, the UE may retain and use the first identity information until the handover procedure is completed and the second base station has obtained the UE context information from the first base station. If an RLF occurs before completion of the handover procedure, the UE may then use the first identity information to perform one or more subsequent connection attempts (rather than using any new identity information provided from the second base station or other intermediate base stations provided in subsequent connection attempts). In this way, subsequent base stations to which the UE attempts to connect will receive identity information associated with the first base station from which UE context information may be retrieved.

An example of an embodiment of this alternate procedure may be described in conjunction with the timing diagram **700** of FIG. **7**. In this example, the handover process may proceed as described previously with respect to FIG. **6**A through stage **618** (e.g., receipt second identity information from eNB **650**, including PCI2 and C-RNTI2). However, at stage **720**, UE **610** may retain the source or first cell identity information. This information may be, for example, a UE identity associated with the first cell, such as S-TMSI1, C-RNTI1 and an initial random number, and/or other UE identity information. The first identity may also include a PCI associated with the first cell and eNB **630**, such as PCI1 (e.g., when C-RNTI1 or S-TMSI1 is used). If the connection then fails at stage **722**, UE **610** may detect and declare RLF. It is noted that, while the RLF detection and declaration at stage **722** is shown as occurring subsequent to transmission of RRCConnectionReestablishment message **643**, in some cases it may occur before transmission of this message. Aspects relating to additional procedures that may be used to address this condition are described subsequently herein. The first identity information may be retained by the UE **610** and used for subsequent connection attempts (rather than using the second identity information) until a data connection is established with another cell.

For example, as shown at stage **724**, UE **610** may attempt to connect to another cell. This cell may be, for example, the first cell and associated eNB **630**, third cell and associated eNB **650**, or another cell. For purposes of illustration, FIG. **7** illustrates transmission of an RRCConnectionReestablishmentRequest message **751** from UE **610** to base station eNB **670** of a third cell, however, as noted previously, reconnection may also be attempted in some cases with the first cell, second cell, or another cell (not shown). In particular, at stage **724**, UE **610** may again use the first cell identity (e.g., S-TMSI1 or C-RNTI1, first random number and PCI1) in performing the RRCConnectionReestablishmentRequest procedure, rather than a subsequently received identity (such as PCI2 and C-RNTI2). eNB **670** may then reply with an RRCConnectionReestablishment message **753**, and may retrieve UE context information from eNB **630** at stage **772** using the first identity information. UE **610** may send an RRCConnectionReconfigurationComplete message **755**, and eNB **6709** may send an RRCConnectionReconfiguration message **757**, which UE **610** may respond to with RRCConnectionReconfigurationComplete message **759**. The UE may confirm receipt of the RRCConnectionReconfiguration message **757** in various ways. For example, the UE may receive a Hybrid Automatic Repeat Request (HARQ) ACK/NACK at layer 2, the UE may receive downlink grants from the target eNB, or through other mechanisms. At stage **782**, the UE context may be stored and data transmission resumed to the UE **610**.

However, in some cases, multiple radio link failures (RLFs) may occur, as shown, for example, at stage **792** (in which case, messages **755**, **757**, and/or **759** may not be sent, and stages **772** and/or **782** may not be performed. For example, if connection to the third cell and associated eNB **670** fails, UE **610** may then attempt to connect to a fourth cell and associated base station (not shown), or may attempt to reconnect with a previous cell, such as cells **1** or **2**. In this case, process stages **720**, **722**, and/or **724** may be repeated, with the UE using the first identity information for subsequent connection attempts. This may be repeated successively through an arbitrary number of connection attempts, and/or until a termination event occurs, such as expiration of a UE timer such as Timer **311** or a successful connection event. Upon successful connection to the third (or subsequent) base station, the UE may use the newly provided UE ID (e.g., the third ID if the connection to the third base station **670** is successful. In the case of multiple RLF, the UE ID associated with the next successful connection may be used for further communications.

Attention is now directed to FIG. **8**, which illustrates details of an embodiment of an example process **800** for facilitating a handover in a wireless communication system. At stage **810**, first identity information may be received at a user terminal, such as a UE, which may correspond with UE **505** of FIG. **5** and/or UE **610** of FIG. **7**. The information may include first user terminal or UE identity information associating the terminal with the first cell and/or first cell identity information identifying a cell from which the context of the terminal may be retrieved. The first cell identity information may be associated with a first cell, such as cell **510** of FIG. **5**, and be provided from a corresponding first base station, such as eNB **512** and/or eNB **630** of FIG. **7**. At stage **820**, the first identity information may be stored in a memory of the user terminal

At stage **830**, establishment of a connection, such as a forward handover between the first cell and a second cell, between the user terminal and a second base station of the second cell may be initiated. The connection may be initiated based on a forward handover, a radio link failure (RLF), and/or some other event such as, for example, as described with respect to FIG. **5** and/or FIG. **7**. The user terminal may then receive second identity information from a second base station, such as base station **522** of FIG. **5** or base station **650** of FIG. **7**, and begin the process of establishing a connection with the second base station. The second identity information may include, for example, PCI2 and C-RNTI2 and a second random number. At stage **840**, a Radio Resource Control (RRC) connected state (RRC_Connected), as defined in, for example, the 3GPP Specifications, may be established with the second base station. This may be subsequent to receipt of an RRCConnectionReestablishment message at the user terminal.

At stage **850**, RLF may be declared. This may be associated with the second base station at a time or process stage between establishment of the RRC_Connected state and completion of establishment of the connection or finalization of the handover to the second base station, such as prior to completion of an RRCConnectionReconfiguration process.

At stage **860**, a connection with a third base station of a third cell may be initiated. The third base station may correspond, for example, to base station **532** of FIG. **5** and/or base station **670** of FIG. **7**. The third base station connection may be performed using the first identity information, such as

S-TMSI1, or PCI1 and/or C-RNTI1 and/or the first random number, rather than using the second identity information received from the second (or subsequently accessed) base stations.

The user terminal may be, for example, an LTE user equipment (UE). The first, second, and/or third base stations (and/or subsequent base stations in a multiple RLF situation) may be, for example, LTE eNBs. Alternately, the second base station may be a non-LTE base station, such as a GERAN or UTRAN base station, and the first and third (and/or subsequent) base stations may be LTE base stations. The first cell identity information may include a Physical Cell Identity (PCI). The first user terminal identity information may include an SAE Temporary Mobile Subscriber Identity (S-TMSI). The first user terminal identity information may include a C-RNTI and first random number.

The third base station may be a different base station from the first base station and the second base station. Alternately, the third base station and the first base station may be the same base station. Alternately, the third base station and the second base station may be the same base station.

The process **800** may further include, for example, establishing an RRC_Connected state with the third base station and declaring a second RLF associated with the third base station between establishment of the RRC_Connected state with the third base station and completion of establishment of the connection to the third base station. The process **800** may further include initiating a connection with a fourth base station of a fourth cell using the first identity information. The process **800** may be repeated one or more additional times with different cells and/or the same cells as were previously accessed or attempted to be accessed using the first identity information so as to complete a handover or other reconnection.

Process **800** may further include, for example, receiving, at the user terminal, a second identity associated with the second cell and disregarding the second identity during attempts to perform subsequent connections, such as during stage **860** or subsequent connection stages (not shown in FIG. **8**). For example, the user terminal may receive second identity information, such as PCI2 and C-RNTI2 from the second base station but may disregard this information when attempting to establish connections with other base stations, such as in the case of multiple RLFs. Process **800** may further include storing new identity information associated with a second or subsequently accessed cell after handover is completed, such as subsequent to stage **860**. Process **800** may further include removing the first identity information from the user terminal once handover is completed. The information may be removed subsequent to completion of the forward handover and associated connection to the third (or subsequent) base station.

In another aspect, a handover procedure may be made more robust during connection failure subsequent to establishment of the RRC_Connected state at a second base station of a second cell as further described with respect to FIG. **9**. FIG. **9** illustrates a timing diagram **900** associated with an alternative handover procedure which may mitigate the effects of an RLF during handover. In this scenario, RLF may occur between transmission of an RRCConnectionReestablishmentRequest message from a UE and completion of the connection with the target base station. For example, processing may proceed as described previously with respect to FIG. **6**A to stage **614**, wherein transmission of LTE Msg1 **913** from UE **610** and receipt of LTE Msg2 **915** from eNB **650** may be performed. For example, upon receipt of Msg1, at stage **918**, eNB **650** may generate a second identity (e.g., C-RNTI2) and send it in Msg2 **915** to UE **610**. At stage **950**, UE **610** has the second identity, and may send an RRCConnectionReestablishmentRequest message **641** (e.g., LTE Msg3) to eNB **650**. eNB **650** may then generate and send an RRCConnectionReestablishment message **943** to UE **610** (e.g., LTE Msg 4). At stage **952**, UE **610** may receive message **943**.

However, an RLF may occur at UE **610** at stage **952** (i.e., after transmission of message **641** and receipt of message **943**), and therefore UE **610** may not be able to complete the connection. UE **610** may then perform a cell reselection procedure and may attempt to reconnect to the second cell and associated eNB **650** at stage **954** (e.g., via a subsequent Msg1, Msg2, etc. signaling). Upon receipt of the subsequent Msg 1 (not shown), eNB **650** may generate, at stage **956**, a third identity (e.g., C-RNTI2-2) for transmission to UE **610**. Upon receipt of the subsequent Msg2 from eNB **650** (not shown), UE **610** will have the third identity. UE **610** may then send another RRCConnectionReestablishmentRequest **955** (e.g., Msg3), to which eNB **650** may then respond with RRCConnectionReestablishment message **957** (e.g., Msg4). At stage **958**, UE **610** will then be in an RRC_Connected state with the third identity (C-RNT2-2), and may then send an RRCConnectionReestablishmentComplete message **959** to eNB **650**.

As shown in FIG. **9**, prior to declaration of RLF at stage **952**, eNB **650** may retrieve UE context information at stage **930**, which may be based on the first identity information provided by UE **610**. At stage **962**, eNB **650** may merge identities (e.g., C-RNT2 and C-RNT2-2) to associate the context information with the merged identity, and the merged identity may remain in the form of the value or data associated with C-RNT2-2. For example, at stage **962**, eNB **650** may associate C-RNT2-2 with the context retrieved initially at stage **930** from the original context information provided by the UE (e.g., source identity information such as C-RNT1, PCI1, or S-TMSI1).

FIG. **10** illustrates details of an embodiment of a process **1000** that may be used to facilitate a forward handover in a communications system at a target base station, such as eNB **650** as shown in FIG. **9**. At stage **1005**, a UE, such as UE **610** as shown in FIG. **9**, may attempt to establish a connection with a target base station, such as target base station **650**. The connection may be initiated by generating and sending a connection message, such as LTE Msg1. The target base station may generate and send second identity information **1010** to the UE, which may be received at stage **1007** at the UE, such as in LTE Msg2. The second identity information may be information generated at the target base station, such as a C-RNTI2 as described previously herein.

At stage **1015**, the UE may send a connection reestablishment request message, which may include full UE identity information. At stage **1020**, the target base station may receive the connection reestablishment message, and at stage **1030** the target base station may receive first identity information from the UE. The first identity information may include information for retrieval of user context information stored at a source or first base station. For example, the first identity information may be first identity information as described previously herein. Stage **1030** may be integral with the stage **1020** of receiving a connection reestablishment message.

The UE context may be retrieved at stage **1040** at the target or second cell from the source or first cell, based on the first identity information. The base station may send a connection reestablishment message at stage **1050**, which may be received at the UE at stage **1035**.

Prior to completion of the connection, the user terminal may declare an RLF at stage **1045**, and subsequently attempt to reconnect to the base station at stage **1055**. At stage **1060**, the base station may generate and send third identity information to the user terminal. The third identity information may be, for example, another C-RNTI, such as C-RNTI2-2 as described previously herein. At stage **1065**, the UE may receive and store the third identity information. The received third identity information may be used subsequently by the UE and base station to continue the connection, such as described below.

At stage **1070**, the base station may receive the first identity information from the user terminal. Based on, for example, knowledge of the previous connection attempt by the user terminal, at stage **1080**, the base station may associate the UE context information with the third identity information. At stage **1090**, the data connection process may continue between the base station and user terminal. At stage **1090**, the data connection process may continue between the base station and user terminal and the UE updates the stored base-station/UE identity with the newly allocated identities.

The first identity information may include, for example, a Physical Cell Identity (PCI) and a Cell Radio Network Temporary Identifier (C-RNTI) associated with the first base station. The first identity information may include an SAE Temporary Mobile Subscriber Identity (S-TMSI). The second identity information may include a C-RNTI (e.g., C-RNTI2) generated by the second base station. The third identity information may include a C-RNTI (e.g., C-RNTI2-2) generated by the second base station (assuming the user terminal returns to the second base station and attempt to reconnect). The method may further include sending an RRCConnectionReestablishment message, wherein the RLF occurs before receipt of the RRCConnectionReestablishment message.

As described previously, FIG. **6**A illustrates an example successful handover procedure wherein UE context is transferred from a source cell to a target cell. FIG. **11** illustrates a timing diagram of a similar handover procedure **1100** where a target cell is unable to obtain the UE context information from a source cell. Specifically, the process may proceed as described with respect to FIG. **6**A to transmission of RRCConnectionReestablishmentRequest message **641** from UE **610** to eNB **650**. eNB **650** may, however, be unable to retrieve the UE context information from source base station eNB **630** at stage **1124**. In this case, in accordance with the 3GPP Standards, including, for example, 3GPP TS 36.331, Section 5.3.7, upon failure to retrieve the UE context, eNB **650** may send an RRCConnectionReestablishmentReject message **1143** to the UE **610**. This will necessitate performance of a new full connection process **1150** at the UE, including performing the full RACH procedure, which may cause connection delay and/or otherwise decrease forward handover performance.

In accordance with some aspects, an alternate procedure, as illustrated in the embodiment, as shown in the timing diagram **1200** of FIG. **12**, may be performed to improve handover performance in the event of context retrieval failure. As shown in FIG. **12**, processing may proceed as shown previously in FIG. **6**A to transmission of an RRCConnectionReestablishmentRequest message **641**. At stage **1244**, eNB **650** may attempt to retrieve the UE **610** context from eNB **630**. At stage **1246**, retrieval of the context may fail. At stage **1248**, eNB **650** may then generate a Context Retrieval Fail message. This message may be provided to UE **610** instead of the RRCConnectionReestablishmentReject message, and may be configured so as to inform the UE to continue the connection process without initiating a new connection. For example, eNB **650** may send an RRCConnectionReestablishmentContextFail message **1251**, which may be received by UE **610**. Upon receipt, the UE may then continue with the connection establishment process at stage **1254**, such as by sending an RRCConnectionRequest message **1261** (but not perform a RACH procedure). eNB **650** may then send an RRCConnectionSetup message **1263** to continue the connection process.

FIG. **13** illustrates details of an embodiment of a process **1300** that may be performed at a base station, such as eNB **650** as shown in FIG. **12**. At stage **1310**, first identity information sent from a user terminal, such as UE **610** as shown in FIG. **12**, may be received at the base station. The first identity information may include information for retrieval of user context information stored at a first or source base station, such as eNB **630** of FIG. **12**. At stage **1320**, retrieval of the user terminal context information may be initiated by a target base station. At stage **1330**, context retrieval may fail. In response to failure to retrieve the user terminal context, the base station may generate and send a context retrieval fail message at stage **1340**. The context retrieval fail message may include information informing the user terminal that context retrieval has failed, but connection processing can continue.

At stage **1350**, a subsequent message may be received at the base station from the user terminal. This may be a connection request message. A connection setup message or a connection reject/release message may be sent at stage **1360**, in response to the connection request. The connection setup message may be an RRCConnectionSetup message. The connection request message may be an RRCConnectionRequest message, and the connection request message may be received without receipt of preceding Random Access Channel (RACH) procedure signaling provided from the user terminal.

FIG. **14** illustrates details of an embodiment of a process **1400** that may be performed at a user terminal, such as UE **610** as shown in FIG. **12**. At stage **1410**, first identity information may be sent from the user terminal to a target base station, such as base station **650** of FIG. **12**. The first identity information may include information for retrieval of user context information stored at a source base station, such as eNB **630** of FIG. **12**. At stage **1420**, a context retrieval fail message may be received from the source base station. This message may be generated by the source base station in response to failure to retrieve user terminal context from the source base station. The process may further include sending a connection request message **1430** to the target base station, without performing a RACH procedure with the target base station. The connection request message may be sent subsequent to receipt of the context retrieval fail message.

The connection request message may be, for example, an RRCConnectionRequest message sent from the user terminal. Process **1400** may further include receiving, from the target base station, a connection setup message, and sending a connection setup complete message. The setup complete message may be an RRCConnectionSetupComplete message.

FIG. **15** illustrates details of an embodiment of a user terminal **1500**, which may correspond to user terminals described previously herein, such as UE **350** and/or UE **610**. Terminal **1500** may include one or more processor modules **1510**, which may include one or more processors as well as associated components, such as I/O modules, buses, memories, programmable devices, and the like. Processor module **1510** may be configured to implement the user terminal/UE processing functions as described herein, and in particular processing functions associated with FIGS. **7**, **8**, **9**, **10**, and **14**. One or more modules **1520** including computer readable media may be coupled to processor modules **1510**, and may include processor executable instructions stored on the computer-readable media to perform the various functions described herein. One or more memory modules **1530**, such as memories configured to store information such as user terminal identity, cell identity, and/or other data or information as described herein may be coupled to processor module **1510** to facilitate performing the functions described herein.

Terminal **1500** may also include one or more transmitter modules **1540** configured to communicate with other wireless network nodes. These other nodes may be, for example, base stations such as eNBs **630**, **650**, and **670**. Transmitter module **1540** may be coupled to processor module **1510** and/or to memory or other modules (not shown) to facilitate performance of the transmit-related processing functions described herein. Similarly, terminal **1500** may include one or more receiver modules **1550**, which may similarly be coupled to processor module **1510** and/or to memory or other modules (not shown) to facilitate performance of the receive-related processing functions described herein, and in particular with regard to base stations such as eNBs **630**, **650**, and **670**.

FIG. **16** illustrates details of an embodiment of a base station **1600**, which may correspond to base stations described previously herein, such as eNB **310**, or eNBs **630**, **650**, or **670**. Base station **1600** may include one or more processor modules **1610**, which may include one or more processors as well as associated components, such as I/O modules, buses, memories, and the like. Processor module **1610** may be configured to implement the base station/eNB processing functions as described herein, and in particular processing functions associated with FIGS. **7**, **9**, **10**, **12**, and **13**. One or more modules **1620** including computer readable media **1620** may be coupled to processor modules **1510**, and may include processor executable instructions stored on the computer-readable media to perform the various functions described herein. One or more memory modules **1630**, such as memories configured to store information such as user terminal identity, cell identity, user terminal context, and/or other data or information as described herein may be coupled to processor module **1610** to facilitate performing the functions described herein.

Base station **1600** may also include one or more transmitter modules **1640** configured to communicate with other wireless network nodes. These other nodes may be, for example, user terminals, such as UEs **310** and **610**. These may also be other base stations such as eNBs **630**, **650**, and **670**. Transmitter module **1640** may be coupled to processor module **1610** and/or to memory or other modules (not shown) to facilitate performance of the transmit-related processing functions described herein. Similarly, base station **1600** may include one or more receiver modules **1650**, which may similarly be coupled to processor module **1610** and/or to memory or other modules (not shown) to facilitate performance of the receive-related processing functions described herein, and in particular with regard to user terminals such as UEs **310** and **610**, as well as base stations such as eNBs **630**, **650**, and **670**. Base station **1610** may also include one or more Backhaul interface modules **1660**. Module **1660** may be configured to communicate using backhaul connections, such as illustrated with respect to FIGS. **3**, **4**A, and **4**B. The interface may be via wired connections, such as S1 connections, and/or may include wireless connectivity, such as X2 connections. In particular, base station **1600** may be a target base station and interface module **1660** may be configured to retrieve UE context information from other base stations, such as a source base station such as base station **630** as described previously herein.

In some configurations, the apparatus for wireless communication includes means for performing various functions as described herein. In one aspect, the aforementioned means may be a processor or processors and associated memory in which embodiments reside, such as are shown in FIGS. **3**, **7**, **15**, and **16** and which are configured to perform the functions recited by the aforementioned means. The aforementioned means may be, for example, modules or apparatus residing in UEs, eNBs, and/or other network nodes, such as are shown in FIGS. **1**-**5**, **7**, **15**, and **16** to perform the connection and handover functions and other functions as are described herein. In another aspect, the aforementioned means may be a module or apparatus configured to perform the functions recited by the aforementioned means.

In one or more exemplary embodiments, the functions, methods and processes described may be implemented in hardware, software, firmware, or any combination thereof. If implemented in software, the functions may be stored on or encoded as one or more instructions or code on a computer-readable medium. Computer-readable media includes computer storage media. Storage media may be any available media that can be accessed by a computer. By way of example, and not limitation, such computer-readable media can include RAM, ROM, EEPROM, CD-ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other medium that can be used to carry or store desired program code in the form of instructions or data structures and that can be accessed by a computer. Disk and disc, as used herein, includes compact disc (CD), laser disc, optical disc, digital versatile disc (DVD), floppy disk and blu-ray disc where disks usually reproduce data magnetically, while discs reproduce data optically with lasers. Combinations of the above should also be included within the scope of computer-readable media.

It is understood that the specific order or hierarchy of steps or stages in the processes and methods disclosed are examples of exemplary approaches. Based upon design preferences, it is understood that the specific order or hierarchy of steps in the processes may be rearranged while remaining within the scope of the present disclosure. The accompanying method claims present elements of the various steps in a sample order, and are not meant to be limited to the specific order or hierarchy presented.

Those of skill in the art would understand that information and signals may be represented using any of a variety of different technologies and techniques. For example, data, instructions, commands, information, signals, bits, symbols, and chips that may be referenced throughout the above description may be represented by voltages, currents, electromagnetic waves, magnetic fields or particles, optical fields or particles, or any combination thereof.

Those of skill would further appreciate that the various illustrative logical blocks, modules, circuits, and algorithm steps described in connection with the embodiments disclosed herein may be implemented as electronic hardware, computer software, or combinations of both. To clearly illustrate this interchangeability of hardware and software, various illustrative components, blocks, modules, circuits, and steps have been described above generally in terms of their functionality. Whether such functionality is implemented as hardware or software depends upon the particular application and design constraints imposed on the overall system. Skilled artisans may implement the described functionality in varying ways for each particular application, but such implementation decisions should not be interpreted as causing a departure from the scope of the disclosure.

The various illustrative logical blocks, modules, and circuits described in connection with the embodiments disclosed herein may be implemented or performed with a general purpose processor, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA) or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general purpose processor may be a microprocessor, but in the alternative, the processor may be any conventional processor, controller, microcontroller, or state machine. A processor may also be implemented as a combination of computing devices, e.g., a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration.

The steps or stages of a method, process or algorithm described in connection with the embodiments disclosed herein may be embodied directly in hardware, in a software module executed by a processor, or in a combination of the two. A software module may reside in RAM memory, flash memory, ROM memory, EPROM memory, EEPROM memory, registers, hard disk, a removable disk, a CD-ROM, or any other form of storage medium known in the art. An exemplary storage medium is coupled to the processor such that the processor can read information from, and write information to, the storage medium. In the alternative, the storage medium may be integral to the processor. The processor and the storage medium may reside in an ASIC. The ASIC may reside in a user terminal. In the alternative, the processor and the storage medium may reside as discrete components in a user terminal.

The claims are not intended to be limited to the aspects shown herein, but is to be accorded the full scope consistent with the language of the claims, wherein reference to an element in the singular is not intended to mean "one and only one" unless specifically so stated, but rather "one or more." Unless specifically stated otherwise, the term "some" refers to one or more. A phrase referring to "at least one of" a list of items refers to any combination of those items, including single members. As an example, "at least one of: a, b, or c" is intended to cover: a; b; c; a and b; a and c; b and c; and a, b and c.

The previous description of the disclosed aspects is provided to enable any person skilled in the art to make or use the present disclosure. Various modifications to these aspects will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other aspects without departing from the spirit or scope of the disclosure. Thus, the disclosure is not intended to be limited to the aspects shown herein but is to be accorded the widest scope consistent with the principles and novel features disclosed herein. It is intended that the following claims and their equivalents define the scope of the disclosure.

We claim:

1. A method for facilitating a forward handover in a communications system, comprising:

receiving, at a target base station, a first message from a user terminal indicative of a Random Access Channel (RACH) procedure to initiate access to the target base station;

sending, from the target base station, a second message to the user terminal to initiate access to the target base station;

receiving, at the target base station, a third message comprising a connection reestablishment request including first identity information from the user terminal for retrieval of user context information stored at a source base station;

initiating, at the target base station, retrieval of the user context information from the source base station;

sending, from the target base station, in response to failure to retrieve the user context information, a fourth message to the user terminal informing the user terminal to continue the forward handover without performing another RACH procedure; and

receiving, at the target base station, a connection request message from the user terminal.

2. The method of claim **1**, further comprising sending a connection setup message to the user terminal subsequent to receipt of the connection request message.

3. The method of claim **2**, wherein the connection setup message is an RRCConnectionSetup message.

4. The method of claim **1**, wherein the connection request message is an RRCConnectionRequest message, said connection request message received without receipt of preceding Random Access Channel (RACH) procedure signaling from the user terminal.

5. The method of claim **1**, wherein the fourth message is a context retrieval fail message.

6. The method of claim **1**, wherein the first identity information comprises at least one of a Physical Cell Identity (PCI) or a Cell Radio Network Temporary Identifier (C-RNTI).

7. The method of claim **1**, wherein the target base station and the source base station are the same base station.

8. A non-transitory computer readable medium including codes executable by a processor of a target base station to:

receive a first message from a user terminal indicative of a Random Access Channel (RACH) procedure to initiate access to the target base station;

send a second message to the user terminal to initiate access to the target base station;

receive a third message comprising a connection reestablishment request including first identity information from the user terminal for retrieval of user context information stored at a source base station;

initiate retrieval of the user context information from the source base station;

send, in response to failure to retrieve the user context information, a fourth message to the user terminal informing the user terminal to continue a forward handover without performing another RACH procedure; and

receive a connection request message from the user terminal.

9. A target base station, comprising:

a receiver module configured to receive a first message from a user terminal indicative of a Random Access Channel (RACH) procedure to initiate access to the target base station;

a transmitter module configured to send a second message to the user terminal to initiate access to the target base station;

wherein the receiver module is further configured to receive a third message comprising a connection reestablishment request including first identity information from the user terminal for retrieval of user context information stored at a source base station;

a processor module configured to initiate retrieval of the user context information from the source base station;

wherein the transmitter module is further configured to send, in response to failure to retrieve the user context information, a fourth message to the user terminal informing the user terminal to continue a forward handover without performing another RACH procedure; and

wherein the receiver module is further configured to receive a connection request message from the user terminal.

10. The target base station of claim **9**, wherein the transmitter module is further configured to send a connection setup message to the user terminal subsequent to receipt of the connection request message.

11. The target base station of claim **10**, wherein the connection setup message is an RRCConnectionSetup message.

12. The target base station of claim **9**, wherein the connection request message is an RRCConnectionRequest message, said connection request message received without receipt of preceding Random Access Channel (RACH) procedure signaling from the user terminal.

13. The target base station of claim **9**, wherein the fourth message is a context retrieval fail message.

14. The target base station of claim **9**, wherein the first identity information comprises at least one of a Physical Cell Identity (PCI) or a Cell Radio Network Temporary Identifier (C-RNTI).

15. A target base station, comprising:

means for receiving a first message from a user terminal indicative of a Random Access Channel (RACH) procedure to initiate access to the target base station;

means for sending a second message to the user terminal to initiate access to the target base station;

wherein the means for receiving is further configured to receive a third message comprising a connection reestablishment request including first identity information from the user terminal for retrieval of user context information stored at a source base station;

means for initiating retrieval of the user context information from the source base station;

wherein the means for sending is further configured to send, in response to failure to retrieve the user context information, a fourth message to the user terminal informing the user terminal to continue a forward handover without performing another RACH procedure; and

wherein the means for receiving is further configured to receive a connection request message from the user terminal.

16. The target base station of claim **15**, wherein the means for sending is further configured to send a connection setup message to the user terminal subsequent to receipt of the connection request message.

17. The target base station of claim **16**, wherein the connection setup message is an RRCConnectionSetup message.

18. The target base station of claim **15**, wherein the connection request message is an RRCConnectionRequest message, said connection request message received without receipt of preceding Random Access Channel (RACH) procedure signaling from the user terminal.

19. The target base station of claim **15**, wherein the fourth message is a context retrieval fail message.

20. The target base station of claim **15**, wherein the first identity information comprises at least one of a Physical Cell Identity (PCI) or a Cell Radio Network Temporary Identifier (C-RNTI).

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